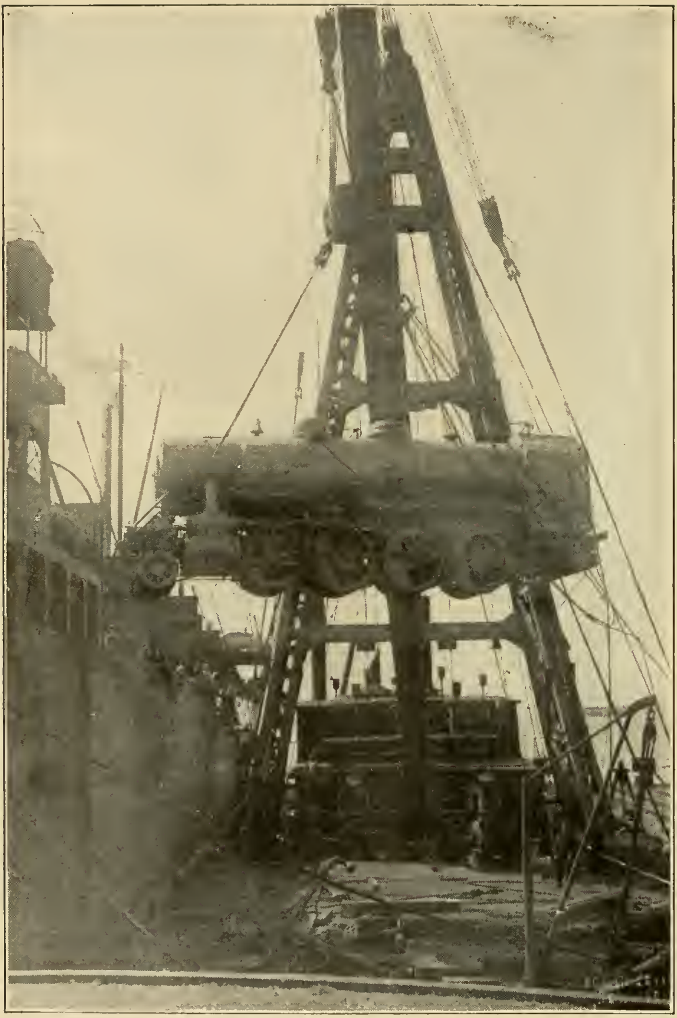
THE AMERICAN ENGINEERS IN FRANCE



LOADING LOCOMOTIVES FOR SHIPMENT TO FRANCE IN CONDITION READY TO RUN

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THE AMERICAN ENGINEERS IN FRANCE

BY

WILLIAM BARCLAY PARSONS, D.S.O.

COLONEL, ELEVENTH U. S. ENGINEERS

ILLUSTRATED

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TO THE MEMORY OF ALL THE AMERICAN ENGINEERS WHO FELL IN FRANCE, AND PARTICULARLY TO THE MEMORY OF THE OFFICERS AND MEN OF THE ELEVENTH ENGINEERS, AMONG WHOM WERE THE FIRST UNITED STATES SOLDIERS TO BE KILLED IN BATTLE IN EUROPE, THIS BOOK IS INSCRIBED AS A SMALL TRIBUTE OF ADMIRATION AND RESPECT

"The British attack at Cambrai is of special interest, since it was here that American troops (Eleventh Engineers) first participated in active fighting."

Extract from Final Report of
Gen. John J. Pershing,
Commander-in-Chief,
American Expeditonary Forces.

PREFACE

This book is not intended to be a history or detailed account of the work done by American Engineers in France. Their work was so extensive and so varied as to put the writing of its record beyond the powers of one man, for none could know it all. It is hoped that some day the record will be properly set forth in justice to the men and for the honor of the profession, but it will be of necessity the joint product of several collaborating authors.

The first contribution that America made to the Allied cause was the raising of nine regiments of engineers, with one of which the author served. It is their work that is the motif of this book. In the writing, it has been necessary to touch on all the fields of engineer activity, because these regiments came in contact with every field, even if they did not invade each one, from constructing ports to digging and holding trenches, in all parts of France from the Atlantic to the Vosges, from the Mediterranean to Flanders. Consequently there results a brief outline of what all engineers did. Perhaps, it may serve to give those who did not go overseas a picture of what is meant by engineering in modern war.

There will not be found any description of spectacular or dazzling pieces of construction like so many structures in civil works that arouse admiration. There was none such. Military engineering consists in doing things in the simplest and quickest way, where permanency in character and accuracy in execution yield to the imperious demands for results that are immediately available regardless of all other considerations. The individual accomplishments that can be singled out with pride were

principally in the application of physics and chemistry. The achievement in engineering construction that was so very noteworthy lay in a great whole.

No reference will be made to the Italian campaign, because no unit of the original nine engineer regiments served there. Much of the work, however, that was done by the Italian engineers among the crags and precipices of the Alps was exceedingly brilliant.

A few personal experiences of the author and others have been introduced, not because they are in any way remarkable, but rather because they are not remarkable. A narrative of the work of the engineer would not be complete if it were not accompanied by at least some suggestions of what entered into his daily life and what were his relations with the engineers of the Allied armies.

In this book the words Allies and Allied Forces refer to the union of nations on the western front, to whom the designation Entente is very frequently, and perhaps with accuracy, applied. The opposing forces were also allied with each other, but by those serving in France they were always thought of as the enemy. To the American Engineers the word Allies meant friends only, and principally the French and British Armies with which they were associated.

The thanks of the author are gratefully extended to Major General Black, Chief of Engineers, for permission to obtain information from the reports on file in his office; to Major General Langfitt, Chief Engineer Officer, A. E. F., for data contained in his full report; to Colonel H. H. Maxfield, General Superintendent of Motive Power; to Lt. Col. J. P. Hogan, G. S.; to Lt. Col. H. W. Hudson, R. T. C.; to Major N. A. Middleton, 23rd Engineers; to Major W. A. Cattell, officer in charge of engineer historical documents; to Captain Fenwick Beekman, M. C.; to Captain E. G. Simons, 56th Engineers, to many officers of the original nine regiments, and to Mr. Frank-

lin D. Roosevelt, Assistant Secretary of the Navy. The statistics have been taken in large measure from "America's Munitions" and "The War With Germany."

WM. BARCLAY PARSONS,

Colonel, 11th U. S. Engineers.

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CHAPTER I

THE NEW MILITARY ENGINEER

The effect of the war on the military engineer, or rather upon his relative importance and personal qualifications, has been completely revolutionary. There was a time when engineers were exclusively military men, when the great pieces of construction other than in architecture, or those which were beyond the limits of the art of ordinary builders, were fortifications; while the only intricate types of machines, very crude affairs when measured by modern standards, were engines of war. There were no magnificent specimens of structural or mechanical construction, which are such an integral part of our daily life as to be accepted as matters of course, and scarcely draw forth momentary comment. Works of a civil character which did exist, were on a very modest scale, and were executed under the direction of military engineers who were described by the single word "engineer"—there being no other kind.

Perhaps the most striking illustration of the military engineer covering the whole field of construction was Leonardo da Vinci, great artist, but greater constructor, whose life's work was the designing and building of crenelated walls, revolving canon, hoisting engines, canal locks, city improvements, and curious machines of all sorts for his illustrious patron, Duke Ludovico Sforza of Milan. For his amusement only, he snatched occasional moments from his arduous tasks of computing to place in color such creations as "The Last Supper," or the elusive smile of "Mona Lisa." He fully expected to go down in history famous as an engineer, and never dreamed that his fortifications and canals were to be for-

gotten and that his reputation was to rest finally on his brush. His survival as an artist is a good example of the instability of prominence in scientific achievement where each advance so completely obliterates previous efforts as almost to eliminate them from the records, leaving the latest word as the sole thing that men know and value. Perhaps, after all, it is only success in art that is enduring, because in art it seems possible to achieve results that other generations delight to remember. Science, the sister of art, is ever in a state of flux and unrest.

The supremacy of the military engineer was challenged in the 18th century, when canals, harbors, lighthouses, roads, and other works, disassociated from any military connection, began to assume a more ambitious character, so as to approach in magnitude the works of national defense. Smeaton, the designer and constructor of the famous Eddystone lighthouse, assumed the designation of "Civil Engineer" to distinguish himself from his military confrères. With the application of steam as a source of power, the field of civil engineering broadened tremendously, and not only surpassed in extent that of military engineering, but became so large that by custom it has been found convenient to subdivide it into mechanical, mining, electrical, and other applications of engineering science, leaving the original term "Civil Engineering" to cover general construction only.

As the civil engineer grew in importance, he not only invaded but took unto himself fields of activity heretofore considered as the exclusive property of his military brother and whilom superior. But contraction invariably leads to solidification. As the range of work of the military engineer became narrowed, so his experience led him to think more and more in terms of rigidity as shown in massive types of military defense, great forts with masonry walls as designed by Vauban and other masters. When progress in creating new or developing

previously known building materials gave him steel, heavy castings, modern concrete, he was carried still further toward immobility with great guns permanently fixed on solid emplacements, mounted on intricate disappearing carriages or covered with shields capable of resisting any blow that could be imagined by him. The last word seemed to have been spoken.

It had been spoken. Military engineering science had unconsciously reached an impasse. The old military engineer was, quite unknown to himself, moribund, and needed but the supreme test of experience to prove that his theories were dead. But in his death he was to have his revenge on his brother civil engineer, for his art was to have its resurrection into a new and bigger art, full of life and mobility, and he was to become again the great exponent of applied science.

Progress is always made along spiral and not straight lines, so that after a lapse of time, we seem to come back to our original starting point, only it is on a higher level. It took but a few shots from the German 42 cm. guns early in the war to smash the great masonry and steel defenses of Belgium and northern France; defenses deemed impregnable and the very perfection of the military art. As they cracked and crumbled under the pounding of these new monster engines of war, the whole science of military engineering, as the masters had conceived it, likewise crumbled and what had taken centuries to develop became obsolete in a twinkling.

This did not mean that the military engineer had ceased to exist; quite the contrary. It soon was apparent that a new military engineering science had been born enormously greater in extent and composition than the old that lay buried under the ruins of Namur and Maubeuge. The new field included every form and application of civil engineering, using the term in its broadest significance, and with it, electricity, chemistry, physics,

metallurgy, geology, and bacteriology. While formerly the military engineer need only know about tenailles, bastions, glacis, counterscarps, and other details of permanent fortification, together with only the rudiments of roads, bridges and surveying, to-day there is almost nothing in the whole range of applied science that he should not know something of, and in much of it he must be expert. Railroads and roads, their construction and maintenance, bridges, locomotives, cars, engines of all types, buildings, tunnels, accurate mapping and range finding, water supply and its purification, photography, the laws and practical application of electricity, and the chemistry of gases, liquids and explosives, are part of his every-day work. Nor are these things to be known only in an elementary way. In the military text-books of not many years ago, instruction regarding bridges was confined to pontoon bridges or very simple structures, where perhaps the component members were held together by small ropes. Such structures could carry infantry, or at most, light artillery drawn by horses. Occasionally a bridge of this nature must still be erected, but the bridges with which the military engineer has to deal to-day must be strong and stiff enough to support locomotives weighing 100 tons each, drawing trains of cars, each car with its load weighing fifty tons. These weights in the late war were not the maxima, since after the failure of permanent gun emplacements, it was decided to mount the largest types of guns on railway cars, so as to provide the maximum of mobility. At the conclusion of the war, sixteen-inch guns, heretofore considered possible to use only on the most substantial of foundations, had been actually mounted on and fired from specially designed railway cars weighing 300 tons.

Troops without equipment are worthless, and equally so would be a bridge that would carry the former, but not the latter. The infantry must have artillery and the

greater part of artillery is now motor drawn by tractors weighing ten or more tons, the gun itself, speaking only of those that usually were moved on roads, weighing as much more. Tanks, which also had to be provided for, weighed as much as thirty-five tons. These few figures show that the bridges now to be built are vastly different in design and detail from what would have been erected to carry an army of previous wars. So it was with all the problems facing the engineer.

The military engineer of the future must, therefore, know more of various kinds of engineering than any other engineer. At last he has emerged from the eclipse that began with Smeaton, and can claim to be again the leading type of engineer in that he supervises the highest and most varied applications of science.

In our own service, it has been the custom of the War Department to use the officers of the Corps of Engineers on work other than what was known as military engineering, principally in the development and improvement of our rivers and harbors. This practise brought them in contact with many phases of engineering which they would not have met had they been confined to strictly military problems as they existed before 1914, and undoubtedly had great effect in preparing them to handle the unexpectedly new problems that were thrust upon them during the war. As the art of war now stands, military engineering is advanced civil engineering, with the application of every-day methods and engines to the requirements of war. The proper training of military engineers should, therefore, be largely along lines of civil practise and experience. It is to be hoped that the War Department will maintain its wise policy of the past and give the army engineers as wide and broad a connection as possible with all matter of public works. Whatever the Government has to do in such matters should be given to the officers of the Corps of Engineers of the army,

thereby training them during periods of peace for the very duties that they will be called on to perform should war again come.

One measure of the importance of the engineer arm was the number of engineer troops engaged. In April, 1917, when the United States declared war, the engineer forces of the regular army consisted of 256 officers and 2,198 men, with but one general officer, the Chief of Engineers holding the rank of Brigadier-General. This force, small as it was, nevertheless had been increased greatly to meet the requirements arising out of the troubles with Mexico along the Rio Grande beginning in the previous summer. It was widely scattered in different parts of the United States and our overseas possessions. Nineteen months later, when the armistice was signed, there had been sent to Europe considerably more than 11,000 commissioned engineer officers and 234,000 enlisted engineer men, while there were in camps in the United States 15,000 more men ready and waiting sailing orders to join the expeditionary forces in France.

These troops were distributed approximately as follows:

With armies at the front.....	86,400
Transportation Corps........	60,000
Construction................	43,000
Forestry....................	18,500
Training schools, etc.........	18,500
Supplies....................	7,600
	234,000

But this total, great as it was, did not represent the whole of the engineer force. In addition to the units classified as engineers and the attached service battalions, there were twenty-four regiments known as Pioneer Infantry who went overseas. Although these

regiments were organized, armed, and drilled as infantry, and equipped and trained to fight in an emergency, they were intended primarily to act as assisting forces to other arms. Nineteen of these regiments aggregating about 1,600 officers and 52,000 men, were assigned to the engineers and were used chiefly in constructing railways and roads in the advanced area. Besides the Pioneer Infantry, there were employed by the engineers prior to the conclusion of hostilities, 34,000 civilians and 15,000 prisoners of war.

The total aggregate of engineer troops, officers and men, actually in France can be put down as approximately 347,600. This was a long step from the 2,454 officers and men who constituted the Corps of Engineers on the 6th of April, 1917. Had the war continued another year, the above total would have been exceeded by a considerable figure, because plans were already formed to increase the transportation corps alone to 150,000 men.

To direct the work of this army of engineers, there were four major-generals, sixteen brigadier-generals and many colonels acting as brigadiers, most of whom would have been given that rank had not the armistice cut short operations and all promotions.

It is frequently said that figures do not lie. Perhaps so, but at any rate, when stated thus baldly, they do not accurately convey the whole truth through failing to give a complete and perfect impression of their full meaning. As a measure of comparison, it may be convenient to recall that the combined federal and confederate forces under Meade and Lee at Gettysburg numbered less than 160,000, while the whole of the great armies under Wellington, Napoleon, and Blücher at Waterloo, armies that represented the best part of the peoples of Europe, totalled about 345,000 officers and men.

As the new military engineer had been created during and as the result of the war, so the engineer forces had

to be developed on a scale wholly out of proportion to those needed in any previous war. It was a great task that faced the American engineers; it was a great force that was needed to cope with it. The force was raised and the task was accomplished.

CHAPTER II

THE FIRST AMERICAN ENGINEERS

During the first two years of the war, the great majority of the American people deceived themselves with the comforting belief that the Atlantic Ocean separated them so effectually from European politics that, in no case, could the war be any affair of theirs beyond selling to the belligerents supplies that temporarily they could not produce for themselves. The people could not see that mighty forces beyond their control and the control of statesmen, no matter how wise, were slowly but inexorably drawing them into the conflict.

The echoes of Louvain, of Charleroi, of Joffre's masterly retreat and victory on the Marne had scarcely ceased to sound before some American engineers realized that the war had already brought to the front not only new problems for the engineer to solve, but that, if the war were to continue beyond the stage of a short sharp campaign on which the Germans based their plans and hopes for victory, there would be a call for engineers and engineering science beyond even the most liberal estimates of military authorities. They also recognized, if the majority of their fellow-countrymen did not, that each day the war lasted, made our participation nearer the inevitable. To the lay mind, the ocean might appear to be an insuperable barrier. As engineers these men could see in their trained imagination the possibilities of improvements already at hand, by which troops could be transported in large numbers, and to them there was needed but the demand to make the crossing of the ocean feasible not only by ships upon the surface, but by submarines beneath it and by airplanes or dirigible balloons

above it. They knew that their science recognized no limits that could not and would not be surpassed.

As early as February, 1915, a small group of engineers met at a luncheon in New York to consider plans to prepare the members of the civil branch of the profession to meet the call that they saw coming.

At that time there was no extensive machinery by which either engineers could receive military training or whereby the Government might call on them for service if needed. A very few engineers in some states could attach themselves to units of the National Guard. That was all. Some years previously, the United States Government had organized the Medical Reserve in which doctors could be commissioned as offcers of the army in reserve, to be called to service when needed, and again to be released to the reserve when the emergency had passed. This group of engineers decided that there might well be organized an engineer reserve on precisely similar lines, because engineers, like doctors, were doing in peace time and in their ordinary occupation the very things that they would be required to do if called to war. As a result of this quite informal gathering, the five national engineering societies appointed committees to formulate a plan. In order to correlate efforts, a joint committee representing all the engineering institutions was organized, composed of the chairmen of the separate committees. This joint committee was instructed to lay the suggestion of an Engineer Officers' Reserve Corps before the War Department for consideration. The committee was cordially, and the plan proposed sympathetically, received by the Secretary of War, Mr. Garrison, the officers of the General Staff, and the Chief of Engineers, Brigadier-General Bixby.

After a careful analysis, Brigadier-General (afterward General) Tasker H. Bliss, assistant Chief of Staff,

remarked to the committee, "You have proved your case so far as it relates to the engineers, but why restrict it? Why not extend it to include all arms of the service?" Fifteen months later, this plan became an actuality through clauses in the so-called National Defense Act of 3rd June, 1916, whereby the Officers' Reserve Corps was authorized as part of the army of the United States. This reserve provided the highly valuable machinery for quickly commissioning officers during the spring following, when war was declared, without waiting for the complete legislation creating the National Army, the preparation of which necessarily involved considerable delay. The basic idea of the Reserve and the carrying of it into effect were the first and not the least important contribution by the engineering profession.

In February, 1917, Brigadier-General (later Major-General) William M. Black, Chief of Engineers, seeing that the storm was about to break and realizing the absolutely inadequate size of engineer troops at his disposal, took advantage of the Reserve Act and quietly gave orders for the organization of certain reserve regiments of engineers, and thus found himself in a position to comply with the first call made on the United States when war actually came — a call for engineers.

Immediately following the declaration of war by the United States, the Governments of Great Britain and France appointed commissions known as the Balfour and Viviani-Joffre commissions, to discuss with the American Government how and to what extent it could most effectively and quickly aid the common cause. These commissions arrived in Washington during the last week in April and after suggesting certain general principles of financial and military coöperation, they stated that the most pressing immediate need was for engineers. So, while our Government should create and send an army as quickly as possible, they requested that there

be raised immediately some regiments of engineers. These men, while they must be equipped and made ready for any emergency, were to be used at first in transportation, in the building and maintaining of railway lines from the coast ports to the front line trenches.

The War Department acted promptly on the Anglo-French request for engineers, and ordered nine regiments raised. These regiments were known later as the Eleventh to Nineteenth Engineers, both numbers inclusive. As they were intended primarily for railway work, the word " railway " was included in their designations, but in actual service, as their work broadened, and as they were called on for all classes of engineer duty, the word " railway " was soon omitted from their title.

To raise them quickly, they were distributed as widely geographically as possible, but with headquarters at large railway centers, so as to reach more easily the class of men specially sought. The places of concentration with the numbers of the regiment were:

New York......	Eleventh Regiment
St. Louis........	Twelfth "
Chicago........	Thirteenth "
Boston..........	Fourteenth "
Pittsburg.......	Fifteenth "
Detroit..........	Sixteenth "
Atlanta..........	Seventeenth "
Pacific Coast....	Eighteenth "
Philadelphia....	Nineteenth "

At first, they were spoken of as " reserve " regiments with numerical designations beginning with No. 1, but on the passage of the act authorizing the National Army, the term " reserve " was dropped, and the numbers changed as above. Enlistment for the New York regiment was already well advanced when the Anglo-French

call came, but its commanding officer, realizing that an opportunity was presented for the regiment to be sent immediately to France, accepted the offer that it become one of the first nine regiments.

The men were secured for the most part by calling on the executives of the large railway systems for assistance and for permission to seek volunteers among the personnel of their companies. As some of these regiments were intended originally for specific duties, for railway operation like the Thirteenth, for railway maintenance like the Fourteenth, and for locomotive and car repairs like the Nineteenth, care was exercised in selecting men and officers with corresponding experience. But in the construction regiments, no such nice distinction was necessary, and an intelligent recruiting officer judged applicants on general personal qualifications, so that a strong, eager typist would be classed probably as a machinist, while a clear-eyed clerk without any mechanical experience, but who was obviously of the right mental and physical character, would be set down as a carpenter if it could be shown that he had even once nailed up a packing box. Later this gave the company commanders some bad moments with their consciences (at the beginning nearly every officer had such a handicap as a conscience) in their struggles to show that their several companies had the proper distribution of mechanical trades as required by the regulations. But the interesting thing is that it all came out right in the end; the typist, after short practice, could wield a pick in the trenches as well as anyone; the dry goods clerk, whose knowledge of carpentry was so limited, soon learned to lay the flooring on a bridge, while the college lad with no field experience of any kind would never fail to hit his mark with his rifle.

One case that comes to mind was that of a quiet, reserved private classed as a "miner," but who was

found to have been in civil life a consulting engineer with an extensive and lucrative practice, and who, among other accomplishments, was able to take charge of Hindoo laborers and direct them in their native tongue. Later he was advanced from the ranks to be a professor of geology at the staff college at General Headquarters. Then as an illustration of American versatility on a large and not an individual scale, the commanding officer of one of these engineer regiments was one day called on to send 200 picked men to complete a theatre with a seating capacity of 5,000, the assisting unskilled labor to be furnished to any extent necessary by neighboring infantry. The large building was at the time under roof, but without sides or any interior fittings. The colonel made no selection other than to send one company whose captain could be depended on to do the best possible under the circumstances. In three weeks the building was enclosed, tarred paper on the roof to make it water-tight, seats, including private boxes for distinguished guests, in place; electric lights, moving picture apparatus and colored spot lights for the stage wired and installed, and the scenery painted.

The officers of the nine regiments were for the most part practicing engineers from civil life. Some had had National Guard experience or Spanish War service; some had attended training camps as at Plattsburg, and a few were graduates of the Military Academy at West Point who had resigned from the army. In all cases but one, however, the colonel and adjutant were officers of the permanent establishment, the one exception being an officer who had commanded a regiment of engineers in 1898 but who had resigned from the Corps of Engineers to follow a commercial career.

At the time when these regiments were recruited, there were no provisions of law for a draft, so that all enlistments were voluntary, and an exceedingly high average

grade of man resulted. Many university graduates and engineers holding important positions, turned away from entering officers' training camps where their educational advantages would have soon gained commission recognition, preferring to enlist as privates out of a high sense of patriotism and with the desire to be among the "first to France." In consequence, every one of those regiments provided a large number of officers promoted from the ranks to fill vacancies in their own cadre or those of other units, or for staff duty, or for return to the United States to officer and train new regiments being formed. Thus the Eleventh regiment created no fewer than sixty-eight new officers, and when it returned home, out of fifty-two engineer officers on duty, forty-one had entered the service as privates, including six of the seven company commanders.

The regiments sailed as soon as their equipment had been received, men sufficiently trained and ships became available. They reached Europe either through English or French ports and were assigned to various commands as follows:

REGIMENT	DATE ARRIVAL	ASSIGNMENT
15th	20 July, 1917	American railways
11th	27 July, 1917	British forces
13th	31 July, 1917	French forces
14th	12 Aug. 1917	British forces
12th	12 Aug. 1917	British forces
17th	12 Aug. 1917	Port construction
18th	23 Aug. 1917	Port construction
19th	23 Aug. 1917	Repairs French cars

Their work from the very beginning formed a part of nearly every phase of engineering activity in France from the heavy but highly important construction of docks and warehouses and terminal yards in southern or

central France, where fortunately the devastating blight of war was never seen, to the culminating horrors of the final weeks in the Argonne, where no less than six of the original nine regiments served in unison. They constructed and maintained railway lines all over France, they were charged with the responsibility for the highly important light railways that carried ammunition to the forward guns, they repaired cars and locomotives, they dug and held battle trenches, they built bridges, assisted in water supply and roads, and in short, no group of units was more closely identified and more intimately associated with the whole field of engineering work in France.

When the call for engineers came so suddenly and so unexpectedly as the most pressing need to be first satisfied, the War Department was without the requisite detailed knowledge of just how these first regiments should be equipped and constituted. To procure this information and to arrange for the assignment of the regiments on their arrival in France, a Commission was despatched immediately to Europe to confer with the British and French military authorities, and study the actual conditions in the field. The Commission, consisting of Majors Wm. Barclay Parsons and Wm. J. Wilgus, E. O. R. C.; Capt. A. B. Barber, Corps of Engineers, and Messrs. W. A. Garrett and F. de St. Phalle, received their orders on May 10, 1917, and were thus the first military men except hospital units, to be sent overseas. The three officers became colonels during the war, the first in command of the Eleventh Engineers, the second as Deputy Director-General of Transportation and the third on the General Staff.

This commission, after a rapid inspection of the British and French fronts, of the several ports in France through which Amrican troops could enter, and of the main lines of railway leading from the ports to such portions of the fighting line as might become the American

sector, reported to the War Department that the task which lay ahead was far bigger and more difficult than had been generally supposed, and then for the first time gave a picture of what American engineers and American engineers only must do if victory were to be won. They pointed out that France could not be relied on for any assistance. Not only were the men constituting the army to be sent across the ocean, but also all their supplies of every nature, arms, ammunition, clothing, food. To permit the landing of the men and their supplies, there must be berthing places for the ships. But these berthing places did not exist and the material for them, the piles and timbers, were probably still standing in American forests. When the piles and stringers for the wharves had been felled and sawed to size, had been sent across the ocean and erected into wharves, there were no camps for the soldiers to move into or storage buildings to house the perishable supplies. After landing the men and supplies, they could not be moved from the base ports until locomotives and cars should be sent from America, because France no longer possessed enough rolling stock to meet its own needs. Nor could France equip the trains thus provided with the required crews, as there was no surplus of man power. Locomotive- and train-men, like the locomotives and cars, must come from overseas, and, finally, the very rails must be manufactured and sent abroad to permit the moving of the trains from the seaboard to the front.

It was an appalling picture, but subsequent experience has shown that if the commission erred in judgment, it was in underestimating and not in overestimating the requirements. If, in the painting of the picture, they failed to make the blacks deep enough and the reds sufficiently lurid, they did succeed in making clear to Washington that at least there was a great part for the engineers to take.

CHAPTER III

AMERICA'S PROBLEM

The problem presented to the engineers of the armies of France, Great Britain and the United States was in principle substantially the same — the provision of ways of offense and defense, the maintaining of all lines of communication, the transportation of men, arms, ammunition, and supplies, the means for evacuating the wounded and ill men and provision of places for their care. But the conditions surrounding the problem for each separate nation were so lacking in similarity that the problems themselves differed so in detail as to become quite distinct one from the other. This was especially true of the American problem.

If France had the misfortune to furnish the battlefields, to meet directly the shock of war, and to be subjected to all the intense suffering and physical destruction while her cities and towns and very fields were laid waste, her armies had at least the advantage of fighting on home ground. Many supplies had to be brought from abroad, but there were French ports and port facilities to receive them. The main lines of interior transportation, railways, canals, highroads, either belonged to the Government or stood ready for Government use with their organizations as going concerns and their full complement of trained employees. On these lines there might be needed from time to time some readjustment of details or connections to meet the changing conditions brought about by the war, but comparatively little in the way of the creation of new facilities. For France's own supplies that were produced at home, every farm, every farm building, every mine, every forest, every factory,

became a part of a great system of national storehouses. From the mines and forests could come the coal and ores and timber as needed; in each little barn could be stored the crop raised on the adjacent farm and it could be kept there safely until called for. The output of the factories was consumed as fast as it was turned out. There was, therefore, little or no need for new vast buildings for holding supplies. When soldiers were allowed furlough, they could go home to rest or, better still, to work on their own farms — as was usually the case. When they were convalescing from wounds or illness, they were sent home for care. In either case, they not only ceased to be a burden on the authorities, but frequently became producers, for a time at any rate.

France's problem can be called a national rather than an engineers' problem. This does not in any way detract from or involve a lack of appreciation of what France, the French nation, and the French General Staff accomplished. Their problem was a mighty one, and it was solved in a manner that will win increasing admiration the more it is studied as future ages roll by. Only it was a problem different from that presented to either Great Britain or the United States.

For Great Britain the war was not one at home, but abroad. The British Government had to arrange to send an army overseas and there maintain it. For this army, England was the base, distant only 30 to 120 miles from the French coast, according to ports. It is true that a part of the army came from afar, from Canada, South Africa, India, New Zealand, Australia, her colonies who responded so nobly to the call for imperial defense, but the major portion came from the little islands that go to make Great Britain and Ireland.

To Britain's army, aided by what remained of Belgium's, was assigned in general that portion of the front extending from the North Sea to a point east of Amiens,

but varying from time to time at the latter end, according as the line of division between the British right and French left was shifted. To provide gateways of access to this territory, the French turned over to the British and for their exclusive use, all ports north of and including Le Havre; that is, Le Havre, Dieppe, Boulogne, Calais, Dunkerque and, in part, Rouen. A glance at the map of France shows these ports to be in a line, and roughly speaking, parallel with the battle front, distant in a straight line only fifty miles at Calais to 125 miles at Havre. The important arteries of railways as well as some 3,500 miles of highways, were under British control for maintenance and operation. In this area, all through railway traffic was suspended, except coal from such of the French mines north of Arras as still remained out of German hands. Furthermore, the civilian population, especially toward the front, had been evacuated to a great extent, thus relieving the railways of a large part of pressing local commercial traffic, and permitting them to be devoted almost exclusively to military purposes. This minimum of civilian interference and the shortness of the haul, rendered the problem of military transportation in the north as simple as war conditions permitted.

Before the era of railways there was constructed in France an extensive and well designed system of canals covering nearly the whole country. In fact, in time of peace it was possible to go by boat through the canals or canalized rivers from the Rhine in Germany to the Atlantic Ocean or Mediterranean Sea. These canals are of two classes in size. On the first class boats 126 feet long drawing six and one-half feet and with a burden of 300 tons can be operated, while on the smaller canals the size of boat is reduced to one of seventy-five tons. As French industrial life had, to a great extent, adjusted itself to these highly useful waterways, in fact, the only

main lines of transport prior to the introduction of steam railways, the whole canal system had been maintained in excellent physical and operating condition up to the commencement of the war. In the British sector, the canals which reached several of the ports, including Calais, were of the first class, and proved of enormous benefit to the British army by relieving the railways of a burden of heavy cumbersome freight for which fast transport was not essential, of the evacuation of some of the wounded who were moved more comfortably on a slow moving canal boat than on a noisy jarring train, and of much matériel that could be sent direct from English ports in barges and towed through the canals to points of consumption without breaking bulk or rehandling. The amount of matériel thus handled monthly exceeded 300,000 tons.

Great Britain could not rely on France for any supplies except some lumber; all had to be transported. Such portion of the supplies as came from overseas was stored in England, and moved from there as needed, together with the output of her own mines, mills, farms, and factories. For the British army, England was, therefore, the depot and, although cut off by water, her large and efficient navy, operating from its own bases, was able to afford reasonably satisfactory protection.

Great Britain's men who were wounded, ill, or on leave, could be and were taken or allowed to go home almost as conveniently as were the French. Although this was not true of the colonial troops, nevertheless they could go, if not to their own homes, at least to those of their own people, and be removed from a foreign even though friendly country and the atmosphere of war.

To carry men and materials across the narrow waterway between England and France, any type of boat could be used, in fact, the moderately small vessel was the most convenient. They were easily manoeuvered, quickly loaded

and discharged, less subject to attack, and if lost, the loss was comparatively small, while French ports, especially the northern ones, were by original construction, adapted to such vessels. These smaller cargo carriers provided a steady, continuous inflow of men and freight, and when traffic is thus delivered, there is needed but the minimum of facilities and labor.

On account of the nearness of the base, the many and short lines of communication in France by rail, canal and water, it was not necessary for Great Britain to keep on hand an extraordinary amount of supplies in the former country. In fact, enough ammunition and food to supply the army for two or at most three weeks was deemed to be sufficiently generous.

The difference between the French and British problems lay chiefly in the separation of the latter's base from the actual theatre of operations and thereby introducing some water transport for men and all materials.

The American problem resembled the British in theory in that the base lay across the water, but having stated that, further resemblance ceased. The details were so dissimilar, the distances so vastly greater, that the American problem was in a class quite by itself.

The first Commission, as explained in the previous chapter, reported fully to Washington. The French military authorities were very frank in stating that the American army must provide itself with every requirement, that to France it could look for nothing. It was the same as if an army were planning to wage war in a distant and desert country without sufficient ports, with no adequate lines of communication and with absolutely no supplies of any one of the articles needed by a great army in a modern war.

The conditions thus laid down were fixed by the very necessities of the situation and not by any arbitrary decision of the French. As a matter of fact, before the war

ended, France gave the world a number of surprising examples of her latent potentiality, did many things and furnished many supplies, including such articles as guns, ammunition, tanks, and airplanes which, in 1917, were deemed to be absolutely out of the question.

When the Commission of engineers arrived in Europe, the British were using, to their full capacity, all ports north of and including those on the River Seine. Brest, the French insisted, must be reserved as a French naval base. Marseille on the Mediterranean, could not be considered available on account of exposure of approaching vessels to submarine attack in the straights of Gibraltar and nearby waters. For ocean-going vessels, this left only Nantes and St. Nazaire on the Loire, Bordeaux on the Gironde and the small port of La Rochelle midway between the two. Although the import and export traffic of France had been curtailed tremendously by the war, the portion that remained was concentrated at these places, congesting them to their full capacity, and if there were to be any substantial increment in ocean traffic, the facilities for berthing and discharging the ships simply did not exist.

The construction of wharves and piers for the accommodation of vessels is not the simple matter along the French Atlantic coast that it is for the ordinary American port, where some piles, heavy timbers for floor beams and stout planks for decking suffice and can be put in place to make a wharf. Along the Atlantic coast of France there is a serious daily rise and fall of the tide, which greatly hampered rapid work, as it demanded special details of construction and equipment. This variation is the smallest at Pauillac, near the mouth of Gironde, with a mean of 13.7 feet and a maximum of 18.1 on spring tides. The rise increases as the tidal wave runs along the coast, reaching the great figures of 21.7 feet on mean and 28.3 feet on spring tides at Tréport.

Further north there is a decrease, the variation between high and low water at Calais being 16.2 feet on a mean tide and 21.0 feet on springs. The harbor facilities at St. Nazaire and La Rochelle were, therefore, tidal basins into and from which vessels had to be passed through lock gates at high tide only. Such basins are matters of elaborate construction in masonry, are permanent in character, and offer many difficulties for alteration or extension. In actuality, radical development was impossible because surrounding permanent improvements such as streets, buildings, factories, and railways prevented extension. Bordeaux and its subsidiary port, Bassens, across the river and some five miles lower down, were about seventy-five miles from the river mouth, with shoals intervening which restricted vessels even at high water to a maximum draught of twenty-six or twenty-seven feet. All these places were really no more than names. For American purposes, they were not ports. The French promised temporary accommodations for a few ships, but clearly pointed that for the fleet that would eventually arrive, everything must be constructed and all the necessary unloading cranes and other freight handling machinery must be purchased in America and sent out.

The British authorities, as has been shown, could use the existing ports which, without reconstruction, were exactly adapted to the small type of vessel that would naturally be used in cross-channel traffic. Further, these vessels could be expected to arrive and depart at a substantially constant rate. For the American service, the base at New York was some 3,700 miles away, even in a direct line, and long miles they were across the Atlantic waste with submarines abounding. To cover the distance, only vessels of large type were available, and after such a long journey, they must be expected to arrive at irregular intervals. As a matter of fact, they actually

arrived in convoys instead of singly, making the problem still more difficult, because the coming in convoys involved the provision of accommodations in excess of any allowance for an approximate average that would ordinarily be assumed.

The conditions surrounding railway transportation were no less difficult. While in May, 1917, no definite statement could be made as to the sector to be assigned to the American troops, a few facts stood out quite clearly. The British sector was definitely fixed. The French desired, for obvious reasons, where if sentiment played a part, it was a proper and very forceful part, that only French troops should cover Paris. For similar reasons of sentiment the French desired to retain for their own occupation, the extreme right of the front in Alsace next to the Swiss frontier, where a lodgment had been effected in 1914 on the eastern slope of the Vosges in Germany, and was still held. The American sector had, therefore, to find a place between, say, Rheims and the department of the Vosges. It is now interesting to note that at the end the American army occupied nearly the whole of this part of the front.

Taking Toul as the center of gravity of a probable American sector, the distance in an air line from St. Nazaire was about 400 miles and slightly more than that from Bordeaux, but these figures would be very greatly increased by following any selected combination of possible railway routes. This was a very different matter from the corresponding distance between the British front and their channel ports from fifty to not exceeding 125 miles. The difference was really much greater than the numerical ratio of eight to one would seem to indicate, because the routes crossed a part of France where there remained the original population supplemented by the evacuated people from the northern departments. All the local and through railway traffic had to be maintained,

because on this part of the country France depended for the greater part of her supplies for both the military and the civilian population.

For this traffic over a distance as great as from Boston to Washington, there was no rolling stock available, not one locomotive, not one car! The French railway companies had lost much equipment through captures during the first two months of the war, other vehicles had been destroyed, some had been worn out in the ordinary process of use and had been discarded, while many locomotives and cars were so completely in need of repair as to be out of service through lack of men to attend to them. During the war few or no replacement purchases had been made. France no longer had enough rolling stock for its own military traffic and, therefore, could not meet ours even in part. The same was true of the lines themselves. French railways, like their ports, had been adjusted carefully, very carefully, to meet commercial traffic requirements which in France were much more constant than similar requirements in America. The lines, if they had rails, could carry more trains, but the real measure of capacity of a railway is how many cars can be passed through junction points, or made up into trains in terminal yards. These critical points were already fully congested. But not all the rails were in place. On account of the difficulty and expense of importing rails from America and in order to meet the imperative calls from the military lines at the front which must be answered at all costs, the French authorities had, during the two years preceding our entry in the war, removed the rails from many lines of secondary importance. Some double-track lines had been reduced to single lines, and some single lines had temporarily ceased to exist at all. Many of these voids must be refilled to sustain the new burdens.

A margin of supplies in France that might be gener-

ously safe for British demands and conditions was obviously not only dangerously narrow for American requirements, but quite impossible for safety. What would answer for a waterway thirty miles wide would never do for one nearly 4,000 miles wide. But it was not only a question of distance. The ocean-going units were necessarily larger as we have seen. The loss of one would, therefore, be exceedingly serious unless there were already on hand in France surplus supplies similar to the lost cargo. Then, even at best, they could not be counted on to arrive in steady flow, as the small vessels or barges at Calais and Boulogne. It was agreed that nothing less than a supply of all articles to carry the American army for sixty days without replenishment could suffice. Later, the general staff increased the minimum to ninety days, but that was found to be unnecessarily liberal, the enemy submarines failing to be as effective as was feared they might prove to be.

By the word " supplies " is meant not only the food eaten, uniforms worn, and ammunition expended, but a vast category of articles that ordinarily would never be thought of. Hardware and tools of every sort, bakeries, cooking outfits, and mechanical laundries, motors big and little, carts and wagons, railway matériel, plain wire for telegraph and telephone lines and barbed wire for entanglements measured by thousands of miles, harness and saddlery, medical and surgical supplies by train loads, pipes large and small with pumps, furniture, and housekeeping articles, building materials of almost every nature, coal, oil and gasoline, stationery without end. In the Ordnance Department alone, which furnished many articles besides arms and ammunition, there were more than 100,000 separate and distinct items to be sent to the army and the expenditure of this one department to equip an army of 5,000,000 men was estimated to be more than $12,000,000,000, an amount equal to almost half the

total money appropriated by all the congresses of the United States, from the first continental congress down to the declaration of war. Or, to put it in another way, the rate of estimated expenditure by this department would suffice to build a Panama Canal every thirty days. To this huge mass of articles were to be added the many things, from candies and playing cards to books and special clothing furnished by the Red Cross and other similar organizations, which, if not an integral part of the army supplies, nevertheless went to increase in amount and variety the shipments to be made which, finally, aggregated the enormous total of 7,500,000 tons.

It was an army of 5,000,000 men that was foreseen, a number equal to more than three-fourths of the total population of the City of New York, including women and children. Let it be recalled that without outside help and in spite of the enormous quantity of supplies carried in New York's stores and markets, the city could not live for more than two weeks, not for so long as two days in some items, and then, perhaps, a mental picture can be had of what would be needed to maintain such a fighting, working, and constructing army in a foreign country for three months.

For these supplies, orderly storage space must be provided and for the perishable articles, which constituted a very large part of the whole, there must be water-tight buildings, some next the wharves to give temporary shelter when the cargoes were discharged from ships, some in great main supply depots inland, some in more advanced and scattered bases near the battle line to hold the important things ready for immediate use.

Then there loomed up the exceedingly difficult personal question. France's men were home. Great Britain's men could be sent home from time to time. America's men would have the Atlantic Ocean between them and home. Only those could go back across the sea who were

so incapacitated by wounds or illness as to be unfit for further service. Provision must be made for caring not only for the wounded, but for those convalescing from slight disability who, in the case of our allies, would go to their homes for recuperation and the best form of mental as well as physical rest. Then there would be the men on leave, for even soldiers must have a little relaxation. They could not be turned loose in France. Rest areas must be selected, camps laid out and an organization established for the control of the men.

That was America's problem which, in breadth of scope and multitude of detail, staggered the imagination. In this brief sketch of the picture that the War Department faced in the spring and early summer of 1917, no reference has been made to providing for the necessities of the fighting engineers, the men who were to be engaged in digging trenches and holding them, in reconstructing or destroying captured enemy positions, in bridging streams, or in doing the many works of construction incident to an army at the front. All such work was common to the armies of France, Great Britain, and the United States, depending for its extent on the length of front defended. The description in this chapter is to show where and in what respect the engineer problem of the three allied nations differed one from the other.

Of course, all this was known to our enemies. It is easy to imagine how the Germans, with their mental inclination for thorough analysis, worked over the details of the problem. With their belief in their own invincibility and their unbounded reliance in the efficacy of the "U" boat, they easily led themselves to become confident beyond any doubt that the problem could not be solved, that the ships to carry the men and supplies did not exist, and even if built, there were no ports to accommodate them or buildings to house the men or store supplies, or railways to move them, not at any rate for some

years and long before that time arrived, the Hohenzollern standard would be floating over the ruins of Paris, and their own brand of Kultur and barbarism fettered on the world.

Having thus determined that America was as negligible as was "the contemptible little army of England" in the summer of 1914, the campaign of "Schrecklichkeit" became a perfectly safe policy to follow; it was obviously wise to drown helpless women and children, to sink hospital ships and disregard all rights of neutrals. America was powerless. It was really best to defy her so as to bring her into the dance in order to be on hand to pay the fiddler's bill when it was over.

CHAPTER IV

ENGINEER ORGANIZATION

An army at war is employed in two distinct fields, so distinct that they naturally lead to a separation of immediate directive control. There is that part of the army engaged in the forward area in actual fighting, which for the time constitutes the combatant force, and there is the remainder of the army occupied in undergoing preliminary training, supervising bases, maintaining lines of commuication or resting after a period of active service. As wars have become more complicated with a greater and more varied demand for all sorts of supplies, these latter functions have developed enormously in importance, calling for an increased proportion of the whole force.

The normal distribution of an American army, according to this main line of cleavage, was set forth in the United States Field Service Regulations, the little book that was supposed to be the official guide for the army during a war. But its teachings failed to apply in France. These regulations, written long ago with additions from time to time to conform to new experience, contemplated only two contingencies: a war in the United States, where the forces would be at home acting on the defensive, or a war overseas in a foreign enemy country, where they would be acting on the offensive. The possibility of an American army operating in a foreign friendly country, driving an invader out of that country, and for practical purposes being on the defensive, in that it was not possible to take advantage of captured country for seizing supplies or converting it to one's own use, was outside

the range of vision of this otherwise most excellent work. It was necessary to develop a new organization to meet the unforeseen conditions and to harmonize with the established organizations of our allies. The Army of the United States, of course, included the whole military force, no matter where found, whether at home or abroad, but to facilitate operations in Europe, the part that was overseas was called the American Expeditionary Force, and to it was assigned a Commander-in-Chief. On account of the great distance separating the theatre of operations, from the seat of the Government in Washington, and because the A. E. F. was coöperating with two large armies, broader powers were necessarily given to the Commander-in-Chief than the Field Service Regulations contemplated for such an officer. The part of the army that remained in the United States either permanently or waiting transportation overseas, came under the immediate direction of the War Department, and was entirely independent of the Commander-in-Chief, American Expeditionary Force. The officers of the Department controlled all matters concerned with the organizing, equipping, and training of the great army, the erection of cantonments to hold it, the manufacture or purchase of the stupendous mass of supplies needed by an active army in the field, and the building or acquisition of ships to carry the men overseas, their equipment and supplies, in order to meet, as far as possible, the requirements of the Commander-in-Chief, American Expeditionary Force. These officers in Washington were not limited in their vision to the army of 2,000,000 men that were in France, but had in mind and demanding their attention the greater army of 5,000,000 men that America might be called on to contribute if the war should continue beyond the year 1918, which then seemed likely. Their labors were, therefore, directed towards the upbuilding of the larger unit.

The Field Service Regulations divided the theatre of war into two zones, the Zone of the Advance and the Zone of the Rear, the latter in the case of an overseas war to include the home service and water transport. For France this was impossible. The powers and responsibilities of the A. E. F. began only with the coast of France, matters of ocean transport being controlled from Washington. The main principles underlying the Field Service Regulations were made applicable to France so far as was possible, and the territory occupied by the A. E. F. was subdivided into the Zone of the Advance and Service of the Rear. But as all designations and titles were abbreviated into their initial letters, the latter was spoken of as the S. O. R. and it quickly became transformed into the " Sore " Department. Whether or not the unfortunate combination of letters was the real cause for the change of name, the men in the field, while not knowing, nevertheless believed it to be. At any rate, the Service of the Rear was almost immediately changed to the Service of Supplies, and the S. O. R. became the S. O. S.

The Zone of the Advance corresponded to the similar zone described in the Field Service Regulations. It covered the area in which all active operations were being carried on and to a sufficient depth from the front to include the troops thus assigned whether in the line or in reserve. The length of such zone was the length of front held, the width varied with topography and local conditions, but roughly speaking, was about twenty miles. In this zone the authority of the army commanders was supreme, except only as they were subordinate to the personal direction of the Commander-in-Chief.

For the purpose of this book, it is not necessary to describe at length the complete organization of the Service of Supplies, which cared for the soldier from the moment his ship came in sight of the coast of France until

his departure to America. The S. O. S. clothed, housed, and fed him, saw to the obtaining, storing, and forwarding of his arms and ammunition, paid and insured him, created and maintained for his benefit hospitals and rest camps, kept his records; ran a great post office and a telegraph and telephone service; established enormous refrigerating plants, into which whole cargoes of meats were taken with ease, bakeries, shops where old uniforms, other clothing and shoes were cleaned, repaired, and re-issued; carried into effect elaborate construction of ports and buildings, and operated railways, roads, and canals; organized a police system; in short, touched every phase of a soldier's work, life, and death, and extended its delicate machinery over all of France and in such a manner as to harmonize with French laws and established customs. It was a wonderful organization, but for the moment, we are concerned only with the part of the Service of Supplies that controlled engineers and their work.

The Service of Supplies, being something new to an American army, naturally passed through a somewhat disturbed period of evolution before it finally reached a satisfactory working condition. There is no need to discuss the intermediate stages, except to say that as the perfect machine was being erected, there were many radical changes. Thus the transportation department was completely transformed, except as to the executive head, finally becoming a special corps and reporting directly to the Commanding General, S. O. S.

The huge army of engineers amounting, as was shown above, to about 350,000 men, demanded a complex and very carefully adjusted organization that on one hand maintained rigid military authority and yet permitted freedom of thought and even of action by which the new problems in the application of science that arose almost daily could be solved. The organization had to be

devised so as to direct the great force scattered all over France, to create, lay out, and supervise its work, to insure coördination and coöperation, to avoid friction and especially conflict of authority, to be so flexible that whole units could be transferred promptly from one department to another, to furnish channels of communication, and for the exercise of command that should ramify throughout the services of both the Zone of the Advance and of Supplies. Such an organization had never been attempted in the Corps of Engineers.

It was quite impossible to bring all these engineers under one control, except that nominally exercised by the Commander-in-Chief. As with the army as a whole, the engineers were divided first into two main classes, those serving in the Zone of the Armies and those in the Service of Supplies. In this case the expression "Zone of the Armies" is intentionally used rather than "Zone of the Advance," because for certain administrative purposes it was not possible to have all lines of demarkation between the two zones exactly coincident, and many troops assigned to and under the control of the S. O. S. were engaged in the Zone of the Advance.

For the non-military reader, it may be convenient to recall that the American Expeditionary Force was divided into armies. At the time of signing the armistice, there were two such armies actually in the field with a third in process of formation, which became subsequently the Army of Occupation. An army is composed of several corps, each corps of divisions, each division of brigades, and each brigade of regiments, with certain attached special troops in each case.

To every army, certain engineer regiments were assigned, reporting to and receiving orders from the Army Chief Engineer who was on the staff of the Army Commander. These regiments were engaged with all matters of heavy construction that were the concern of

the army as a whole. The chief engineer of an army was charged with the location and construction of new main railways and the repair and maintenance of old ones. He saw to the building of roads, of light railways to serve troop and advanced artillery positions; the locating of quarries from which might be procured stone for road metal or railway ballast; bridges; the finding of a satisfactory service of water supply and its distribution; the construction of secondary lines of trenches and defensive works of a permanent character; tunnelling and mining operations; the surveying and mapping of the territory occupied by his army or likely to be occupied by it; the care of electrical and other special machinery used in his army area; the determination of enemy battery positions by sound and flash ranging; the study of the geological conditions in the army area and the camouflage protection of the guns, controlling positions, or important buildings. For these varied and complicated duties he was given special troops which, on account of their detail, were called army troops.

Other engineer units were attached to a corps under the general command of the corps engineer on the staff of the corps commander. The functions of the corps engineers were similar to those of army engineers, but geographically, were more restricted, being confined to the operations by the corps taken as a whole. The number of troops thus attached to army or corps was not fixed by any regulation or general order, but varied according to the fluctuating demand of the movements under consideration or in hand.

With each division and forming an integral part of it, was one regiment of engineers, whose commanding officer was ex officio division engineer on the staff of the division commander. This regiment executed all construction work that was assigned to a division or to any of its component brigades. It maintained the local lines of

communication, sited and dug trenches, laid out and built forward defense works, and strung the barbed wire entanglements, erected temporary or small bridges, made surveys, drained camps, and did all the things of a structural nature required by the men on the fighting line. In the case of an advance, the engineers went forward with the division, bridging streams, repairing roads, consolidating the captured enemy positions by reversing their face and repairing shell damage, and erecting new wire entanglements. If the advance were only a raid, that is, an attack followed by an immediate withdrawal before an enemy counter attack could be launched, the engineers destroyed enemy guns, dugouts, trenches, and all other works in the time available. In case of retreat, they formed part of the rear guard, demolishing roads and bridges or erecting obstacles to delay the enemy pursuit. Fortunately, in the war just ended, American engineers were not called on for this last duty. While all special troops were spared as much as possible, the army, corps, or division engineers were always regarded as available to be used as infantry in case of emergency, and were frequently detailed to hold and defend by hard fighting, the trenches that they had built.

It is not without interest to point out in connection with actual fighting that the ratio of death casualties in battle among officers to similar casualties among men was higher with the engineers than with the infantry, artillery, or cavalry, and that the number of battle deaths per thousand officers and men of each arm in France was greater in the engineers than in either the artillery or cavalry, being exceeded only by the infantry.

The total number of engineers, including attached auxiliary troops acting in the Zone of the Advance with armies, corps, or divisions, exceeded 100,000 men.

Engineers in the Service of Supplies were nominally under the control of the Commanding General, S. O. S.,

through various channels. The senior officer, from whom they received orders, was the Chief Engineer, A. E. F., an officer on the staff of the Commander-in-Chief. This office was held first by Brigadier-General Harry Taylor and finally by Major-General William C. Langfitt (originally Colonel, Thirteenth Engineers), both members of the Corps of Engineers, U. S. A.

Although nominally an officer of General Headquarters, the Chief Engineer, for reasons of convenience, established his headquarters not at G.H.Q., at Chaumont, but at the headquarters of the S. O. S. at Tours. As Chief Engineer, A. E. F., he had charge of all engineering construction and work in France, both within and without the Zone of the Advance, and came, therefore, in contact with the army commanders and the Commanding General, S. O. S.

The work of the engineers in the army zone has already been outlined. The channel of communication between the higher engineer command, the Chief Engineer, A. E. F., and the chief engineers of the armies was maintained first through the Director of Military Engineering and Engineer Supplies (D. M. E. and E. S. for short) on the staff of the Chief Engineer at Tours, and finally, as the extent of the American operations increased, through an assistant to the Chief Engineer at G. H. Q.

All construction work, if in connection with ports and harbors, railways, water supply, buildings, hospitals, etc., and also all forestry operations were under the control of the Director of Construction and Forestry, Brigadier-General Edgar Jadwin, original Colonel of the Fifteenth Engineers, the first engineer regiment to reach France, who reported to the Chief Engineer. During the early days of American activity in France, railway construction was executed by engineers attached to the Transportation Department, but finally all such forces were transferred to the Director of Construction and Forestry, who, therefore, had charge of all construction of whatever nature outside of the zone of the armies.

Coördinating with the D. C. and F. was the Director of Light Railways and Roads, D. L. R. and R., at first General Langfitt, but at the last Brigadier-General Charles H. McKinistry, first Colonel of the Eleventh Engineers. It will thus be seen that the first nine engineer regiments furnished four general officers for high staff command, the above three, and Brigadier-General Herbert Deakyne, first Colonel of the Nineteenth Engineers, who was made Chief Engineer, Second Army, on its constitution. The Director of Light Railways and Roads had charge of all light railways, including the principal repair shop and roads except such portions of both light railways and roads as lay within the Zone of the Advance, which it was deemed best to place under the control of the army commanders. The Director reported to the Chief Engineer.

The extended and complex powers of the Director of Construction and Forestry were exercised through a series of section engineers, usually officers with the rank of colonel, among whom was distributed the work as contained in certain arbitrarily defined areas. Under the general command of the Chief Engineer, acting principally through the Director of Construction and Forestry and the Director of Light Railways and Roads, there was a force, as has been shown, of more than 100,000 officers and men.

The next largest aggregation of engineers was found in the Department of Transportation, a department that would have been in another year, one of the largest, if not the largest department, in the A. E. F. The Transportation Corps had charge of the operation of all standard gauge railway lines assigned to American use; of terminal and storage yards; of trains worked by American trainmen on French railways; of a large central machine shop with smaller subsidiary shops for the repairs of locomotives and cars; of the movement of traffic on canals and

the preparation of plans for new railway construction to be carried out by the D. C. and F. This department was composed of about 60,000 engineer officers and men under the command of Brigadier-General W. W. Atterbury, formerly Vice-President of the Pennsylvania Railroad, and an engineer by profession, with the title of Director-General of Transportation, abbreviated to D. G. T. He was independent of the Chief Engineer, except as the latter constructed the lines, yards and structures to be used by his department and reported directly to the Commanding General, S. O. S. As the duties of the D. G. T. increased, a new and separate corps, known as the Railway Transportation Corps (R. T. C.), was created, and all engineer officers connected with transportation were recommissioned, if not originally commissioned, as officers of that corps.

At General Headquarters and elsewhere, there were some scattered engineer units, which, while not comparatively large in numbers, had charge of work of the highest importance. These were the engineers engaged in the making and printing of army maps, in the study of the general geology of France, in the development and working of apparatus for discovering enemy guns or airplanes at night by sound or flash, and in camouflage. They came under the supervision of the Chief Engineer.

Then there were engineers in the Motor Transport Corps. As motors varying in type from high speed motor cycles to huge motor trucks and tractors began to arrive literally by tens of thousands, it soon became evident that another new field of army work had been opened, a field so large and so important as to be worthy of an independent status. These motors had not only to be set up and run, but maintained and repaired, requiring for the last a special shop. The Motor Transport Corps was organized, and as it had reference to troop and supply movement, it was made a department of the Quartermaster Corps.

CHAPTER V

PORTS

In the chapter on America's Problem, it was there shown that one of the great difficulties, perhaps the greatest, in 1917, was to find and prepare gateways through which the army that the War Department had begun to raise, with all its guns, ammunition and other stores, could enter France. At that time the number of 500,000 men was spoken of as the American contribution. To receive even this number seemed to those first on the ground a staggering problem when they saw that France never had possessed port facilities much in excess of her own requirements, that her northern ports had been assigned to British use and that natural physical features forbade rapid construction of additional accommodations. How much more staggering it would have appeared had it been known that provision must be made for an ultimate army of 4,000,000 men, of whom more than half were actually to reach France, and that during each of three consecutive months 300,000 men, with hundreds of thousands of tons of freight, would be landed! Sometimes ignorance, plain dense ignorance, is an ever present help in time of trouble.

To the Engineer Commission there appeared to be only two localities susceptible of sufficient development to furnish immediate relief, the lower reaches of the Loire and the Gironde-Garonne Rivers.

About seventy miles from the bar marking the entrance to the Gironde is Bordeaux, located on the Garonne, which river, with the Dordogne, makes the Gironde. Vessels drawing twenty-eight feet can ascend as far as Bordeaux, the head of masted vessel naviga-

tion, but a tidal rise of about ten feet demands that the passage be made at high water in order to be able to cross certain shoals.

Six miles below Bordeaux and on the opposite or right bank of the Garonne is Bassens, where the French had constructed wharves to furnish facilities for some war industries, which they were extending in the spring of 1917 so as to provide accommodations for ten steamships. Of these wharves, seven were finished. The French harbor authorities pointed out that a second development at least as large as the one in hand could be constructed immediately adjacent to those already built, and until that was completed, some of the berths, perhaps seven, could be placed temporarily at American service. On the other hand, Nantes and St. Nazaire, neighboring places on the Loire, offered many immediate advantages. Four berths at the former and five at the latter were available at once, while St. Nazaire, situated at the river mouth, had twenty-nine feet of water on the lock sills (like many French ports, it consisted of a tidal basin) and was equipped with large lift cranes, capable of handling the heaviest weights.

By July, 1917, the French made the following assignment of existing facilities to continue until such time as they could be replaced by new construction:

St. Nazaire	5 berths
Nantes...................	4 berths
Bassens..................	7 berths
Pauillac (on the Gironde)..	2 berths
La Pallice	2 berths
	20 berths

But it was clearly apparent to everyone that this total of shipping accommodation would pe quite insufficient for the American army whose size people were already

beginning to recognize would exceed the early estimates. What form the additional facilities should take and where they were to be located was the subject of much discussion. With no thought that they were to be the sole creations, it was decided to build, first and simultaneously, at La Martiniere on the Loire and at Bassens continuous wharves capable of accommodating ten ships each. The former project was, however, soon abandoned on account of unsatisfactory foundation questions, leaving Bassens as the only scheme authorized during 1917.

It was decided that probably forty per cent of the A. E. F. cargo could be brought into the Gironde River and handled principally at Bassens, although some of it could be taken care of at Pauillac, where the French had built a wharf capable of accommodating four or five vessels. Being located near the mouth of the river, this port was somewhat more convenient than Bassens higher up. At Bassens the French, according to promise, turned over to American use, seven of the ten berths which they had built there. Subsequently, as they did on many another occasion, they exceeded their promises of coöperation and finally all ten berths were given over to permanent American occupation.

After a trying wait during several months for materials to arrive, work was started in November, 1917, on a ten-berth American wharf immediately below the French wharf, which was ready for taking vessels in the following March. This wharf had a length of 4,100 feet and a width of eighty-two feet. In order to get it in use as rapidly as possible, it was designed according to what might be known as American typical wharf construction, using wooden piles and wooden stringers, covered with heavy planks. As finally constructed there were used no less than 11,000 piles and 4,500,000 feet board measure of timber, nearly the whole of which came from American forests.

The Paris-Orléans Railway Company had a branch leading to the French wharfs. The American engineers constructed, in connection with their own wharves, ample switching facilities, including both classification and departure yards, together with additional tracks connecting the French wharves with the American wharves, so as to make a complete and unified plant to accommodate twenty ocean-going vessels simultaneously.

The American wharves were equipped with forty large American gantry cranes for the rapid unloading of cargo. A continuous line of warehouses was erected in order to furnish immediate protection to perishable goods pending their reshipment to warehouse depots in the interior. This construction, with its many large railway yards and trackage, is the only American project completely equipped prior to the armistice and it stands as evidence of what the A. E. F. would have done in the line of wharf and other construction had the war continued. The gantry crane equipment used on this terminal project more than fulfilled the expectations of those who were responsible for its installation, and Bassens became the chief port of entry for American cargoes.

With the failure to develop La Martiniere on the Loire, Montoir was selected as the site for the chief American port on that river. The original plan called for a wharf 3,230 feet long, to accommodate eight vessels simultaneously, with a double-track trestle bridge 4,000 feet in length. Owing to the lack of construction materials and the difficulty in finding a satisfactory location for this project, due to the peculiar nature of the river bottom, there was considerable delay in commencing the work. In fact, it was not started until July, 1918. At the time of the signing of the armistice, the work was well advanced and would have been ready for complete operation early in 1919. In view of the cessation of hostilities, it was decided to concentrate work of construc-

tion on the completion of three berths and these were finished in January, 1919. This wharf, like the one at Bassens, was of the American type, but it is interesting to note that material for it came from France, the French reversing their first decision that wharf material could not be obtained in Europe. The piles, which varied in length from eighty to one hundred feet, came from trees cut in the Vosges Mountains. While the work at Montoir was being carried out, the American transportation service used the berths at Nantes and St. Nazaire, which had been turned over by the French. Nantes being higher up the river, could accommodate vessels whose draft did not exceed twenty-three feet. Traffic to this point was, therefore, restricted to light-draft, cross-channel vessels or for larger ocean-going vessels, part of whose cargo had been taken off usually by lighters at St. Nazaire, thus reducing their draft to such a figure as would permit them to ascend the river to Nantes.

At the very beginning, Brest had been set aside as not available, because it lacked extensive terminal facilities. There were no berths available where vessels drawing twenty-seven feet could come alongside and, consequently, everything had to be handled by lighter. Brest was the chief French naval base on the Atlantic Ocean, therefore the Government accommodations were entirely reserved for its own use, while the most valuable portion of the commercial port was congested with ships bringing in munitions for Russia and Roumania.

Another disadvantage in the Brest situation was that the outward railway haul was over heavy gradients and was 200 miles longer to the American sector than the line from St. Nazaire, and in order that freight from Brest could reach the American lines of communication, it was necessary that it pass over a single-track line from Le Mans to Tours. The topography of the harbor frontage precluded the possibility

of expansion except at a prohibitory cost both in money and in time for development. During the autumn of 1917 and the spring of 1918, the only use that the Americans made of Brest was one lighterage wharf. Consequently all troops and cargo arriving at Brest were discharged at this wharf after having been unloaded from the transport vessel on to lighters.

With the beginning of the German offensive in March, 1918, and with the realization by all the military high commands that the war would probably be fought to a close during the next few months and that, owing to the intensity of the coming struggle, it was desirable that the full strength of American man power should be brought into play, the whole question of troop transport and troop discharge was again brought under consideration. By this time, the naval authorities in the United States had taken over and had repaired the deliberately damaged German passenger liners that had been kept by their owners in American ports since the beginning of hostilities, which the United States Government had seized on the declaration of war in April, 1917.

The largest of these vessels and, consequently, the most valuable ones for the transport of troops, drew more water than could be found at any French Atlantic port except Brest. The British and French Governments offered to coöperate in the increased delivery of troops through a supply of a greater ship tonnage by the former and by permission of the latter to use the naval facilities in the port of Brest.

As the result of this agreement in the spring of 1918, the American engineers immediately undertook the preparation of extensive plans for the improvement of the port, including the construction of several berths for deep draft vessels and the utilization of the existing jetties. Actual construction of the work was begun in July, 1918. During that and the succeeding months,

when the arrival of American troops in France reached the maximum figures, Brest became the port of entry for all large vessels. The work in hand was finished in September and Brest thereafter was the chief port of troop arrival and of departure until the final return of the army in 1919.

But all the while the plans of the A. E. F. were steadily growing. After the failure to construct a satisfactory port at La Martiniere and while the Montoir project was still under discussion, engineers charged with the responsibility of transport began looking about to obtain other places where landing facilities could be secured or, if necessary, be constructed.

In June, 1917, the attention of Colonel Taylor, the then Chief Engineer, A. E. F., and Major Parsons, the Chief of the Engineer Commission, had been drawn to the possibilities of developing an entirely new port at Talmont, a little fishing village on the right bank of the Gironde River and directly at its mouth. At this point it would be possible to berth vessels of the maximum draft that could pass over the bar and there would be saved the journey up and down the river from the mouth of the river to Bassens, a journey which, on account of the waiting for high tide, would average at least twenty hours in both directions or nearly two days for each round trip of a ship.

The objection to Talmont was its open exposure to winds from the southwest which, should they reach gale proportions, might render this port not usable during their continuance. For this and on account of some local French objections, the use of Talmont was temporarily set aside, but with the impossibility of using La Martiniere and with the steadily growing demand for more and more space — a cry that ceased only with hostilities — Talmont was again taken under consideration in the summer of 1918. After full study of the physical

surroundings, it was decided that the objections could be so reduced that they would not outweigh the natural advantages, and construction was undertaken. As a matter of fact, Talmont was one of the few places where a new extensive water and rail terminal could be created, a combination that was imperatively necessary should the war continue for another year. The plans adopted and approved called for the creation of accommodations for ten vessels, together with the necessary warehouses and track facilities. Construction materials were ordered from the United States and work had been already energetically begun on the construction when the armistice was signed. Then the project, so far as American use was concerned, was abandoned.

During 1917 and the early part of 1918 no consideration was given to the use of the Mediterranean ports on account of the exposure in the approach to these places to submarine attack on vessels coming through the comparatively narrow straits opposite Gibraltar. With the demands for greater accommodations, and as the limit of capacity of the Atlantic ports of France had been reached, it became apparent that recourse must be had to the Mediterranean harbors. By the summer of 1918, the Navy Department advised that sufficient patrol vessels were available to provide the necessary anti-submarine protection. Arrangements were then made with the French for the use of the ports of Marseille, Toulon and Cette. During June the port of Marseille was opened for the use of the A. E. F., and chiefly for the handling of subsistence, clothing, forage, motor vehicles, air craft machinery, rails, gasoline, oil and a few locomotives. The French turned over to exclusive American use nine berths. Later six more, without track facilities, were ready to be turned over when the armistice was signed, the plans for equipping them with the track and unloading facilities having been worked out. Unfortunately,

the existing terminal facilities at all these berths were not adapted to the use of American cars. Had the war continued, the whole track layout would have necessarily been reconstructed. As it was, American cargo was handled exclusively by French equipment and French train crews.

In the autumn of 1918 the French Minister of Marine gave the A. E. F. the use of two piers belonging to the Navy Department at Toulon. Three piers at Cette were also devoted to American use which had been previously given to the British and a few cargoes were discharged by the latter. Had the war continued, this port would have been reconstructed and largely extended for American use.

The above are the main ports that our army occupied, though American traffic went in small consignments to other places, the French coöperating loyally by obtaining facilities from private owners or granting the use of Government space which, at the outset, they considered would not be possible to accomplish.

For administration purposes, the ports operated, or to be operated, by the A. E. F., were divided into groups as follows:

Channel Group: Le Havre, Rouen, Caen, Cherbourg and Honfleur.

Upper Coast Group: Brest, St. Malo, Lorient and Granville.

Lower Loire Group: St. Nazaire, Montoir and Donges.

Upper Loire Group: Nantes and subsidiary small ports in vicinity.

Charente Group: La Pallice, La Rochelle, Rochefort, Tonnay-Charente and Marennes.

Gironde River Group: Bassens, Bordeaux, Sursol, Blaye, Frut, Pauillac, St. Loubès, St. Pardon and Talmont.

Mediterranean Group: Marseilles, Toulon and Cette

Operated Independently: Bayonne.

Eventually to be Operated with Gironde Group: Les Sables d'Olonne.

British Ports: London, Southampton and Liverpool in England; Glasgow, Scotland; Barry, Cordic and Swansea in Wales, and Belfast in Ireland.

It should be stated that the ports of the Channel group which had been assigned by the French to the British were used chiefly for the discharge of men and cargoes reaching France via England, or for the discharge of supplies purchased in England. The British, like the French, realized the importance of American assistance and assigned five berths at Le Havre to American use in the autumn of 1918, with the understanding that the A. E. F. would provide the necessary tracks and warehouses. These berths were put in service before the signing of the armistice.

The total number of berths actually used by the A. E. F. amounted to no less than ninety-seven, of which twelve had been constructed by Americans and eighty-five had been furnished by the French and British.

When it is recalled that the French stated in May, 1917, that all that France could be expected to do would be to furnish, perhaps, fourteen berths at Bassens, St. Nazaire and Nantes inclusive, and that these were to be loaned temporarily only, it will be seen how great was French coöperation and how they not only made good their original promises, but exceeded their estimates, the latter being such a rare experience in the usual handling of construction work.

The labors of the Transportation engineers were not limited to negotiating with the French authorities for the assignment of berthing facilities and the planning of their construction or rehabilitation. At all the new places,

such as Bassens, complete railroad facilities had to be constructed At the already existing ports the track layouts conformed entirely to the French standards. This standard called for parallel tracks connected only by hand-worked turntables with tracks at right angles to the main lines, so that in order to shift a car from one line to the other, it had to be run to one of these small turntables, placed upon the right angled intersecting track, run to the track on which it was desired to be placed finally and again revolved on a hand turntable. This obviously made a very slow and cumbersome operation. In order to get the maximum rate of delivery, these tracks had to be all redesigned, relaid, and connected by means of cross-overs and switches, so that locomotives could shift the cars either singly or in train lots from one track to another But it is to be recalled that at many of these places the existing tracks leading to or actually on the wharves were intersected by city streets. It can be imagined how difficult was any rearrangement when it had to be carried out maintaining the street crossings, with the removal of large buildings, and under an intense railway traffic.

As an illustration, at St. Nazaire such changes and reconstruction to the American standards of switching entailed a total of twenty-five miles of new track. At the same place a double-track railway connection was built approximately four miles in length, in order to provide the necessary additional facilities between the docks and the storage and classification yards so that the supplies from the ship's sides could be removed as rapidly as possible and thus free the vessels for their return journey. This line was built through the city.

The control of the port work was in the hands of a bureau called the Army Transport Service which, prior to the entry of the United States into the war, was operated as a department of the Quartermaster Corps through

the Water Transportation Branch of the office of the Chief Quartermaster General in Washington. All matters pertaining to procuring and allocating tonnage and managing vessels, including the operation of docks, wharves and terminals, were placed under a civilian organization known as the Shipping Control Committee, formed in the early part of 1918, and given the powers of the War Department and of the Shipping Board relative to vessel procurement, allocation and operation. While no definite limit was placed upon the authority and jurisdiction of the Shipping Control Committee, their efforts were confined mainly to home ports. They did not attempt to exercise jurisdiction over the operations of the Transport Service in Europe. They contented themselves with the appointment of a permanent representative of that Committee with G. 1, General Staff, S. O. S.

The Army Transport Service of the A. E. F. was at first operated under the Quartermaster Corps by an officer who had accompanied the Commander-in-Chief to Europe. He was placed in direct charge of the work as Director of Docks. Under the provisions of G. O. 78, G. H. Q., 1917, the Army Transport Service was transferred from the Chief Quartermaster, Lines of Communication, to the Transportation Corps, and this same officer was appointed Director, A. T. S., reporting to the Director General of Transportation.

On May 24, 1918, the Army Transport Service was reconstituted and a standard organization prescribed for all ports with corresponding divisions in the office of the Director, thus affording the necessary control and supervision and a comprehensive development of the terminal organizations. Due to the long continued lack of personnel, the complete organization was not effected until a short time prior to the signing of the armistice.

On the Staff of the Director, A. T. S., were the following:

Deputy Director; Executive Officer; General Inspector; Supervisor of Operations and Chief of Troop and Cargo Divisions; Supervisor of Terminal Facilities; Chief of Inland Water Transport; Chief Marine Engineer and Property Officer.

The organization at the Base Ports comprised:

a. General Superintendent with an assistant in charge of each group of ports.

b. Superintendent in direct charge of each port.

c. Camp Commander reporting to the General Superintendent in direct charge of military affairs.

d. Executive officer in charge of Administration Division.

e. Supervisor of Operations in charge of all Marine operation, including Marine Superintendents, etc.

f. Superintendent, Troop and Cargo Division, in charge of all matters pertaining to troops and cargo from ship's hold to railroad operating department.

g. Supervisor of Terminal Facilities, in charge of procurement, inspection and maintenance of all terminal facilities.

h. Property Officer in charge of all supplies including stevedore gear.

Beginning with a few officers and 491 civilian stevedores, the personnel of the Army Transport Service was gradually increased until at the time of the signing of the armistice it consisted of approximately 800 officers, 22,000 enlisted men, 2,509 civilians and 900 German prisoners, a total of over 26,000 men.

This rearrangement of the Army Transport Service brought the management and operation of all the port facilities under the authority of the Director General of Transportation, where it belonged. The fewer the num-

ber of conflicting bureaus with the consequent division of responsibility and power, the greater the ultimate efficiency.

The British, as has been stated, made great use of the very excellent existing French system of canals which, fortunately for them, led directly from their main ports of entry to the distributing points along the front. The American sector was so placed that, unfortunately, it was not possible for the A. E. F. to make similar use of the French canals. Consideration was given to the utilization of these inland waterways as a means of relieving the overtaxed railroads from unnecessary traffic.

Cargo that arrived at Le Havre and Rouen could be shipped — and was, to a great extent, so handled — by barges up the River Seine, thence by the canals reaching from the head waters of the Seine to various interior points. To the end of January, 1919, the Transport Service handled over inland waterways in France a total of 380,000 tons, not an extraordinarily large amount, though one which afforded an appreciable and very welcome relief to the railway transportation.

The principal part of the construction of the ports was done by the Seventeenth Engineers with headquarters at St. Nazaire and by the Eighteenth Engineers at Bordeaux.

CHAPTER VI

FRENCH RAILWAYS

The entire railway system of all France is composed of two classes of lines, those with a broad gauge and those with a gauge of one meter. The broad gauge has a width between rails of 1.44 meters or, expressed in English measure, of 4 feet 8.7 inches, differing by only two-tenths of an inch from the standard gauge of 4 feet 8½ inches of our own lines. In fact, the difference is so slight as to be negligible and American as well as British car trucks were shipped to France without alterations. The railways of all the principal countries of Europe, except Spain and Russia, have the same gauge as the French. The broad gauge system is divided among five separate corporations; les companies des chemins de fer du Nord, de L'Est, de Paris à Lyon et à la Mediterranée, for short called the P-L-M; de Paris à Orléans (the P-O), and de l'Etat. There is a sixth company, the Midi, but it belongs to and its lines form a part of the Paris-Orléans system, although the company maintains its individual corporate identity. The above companies are all stock concerns with the exception of the Etat, formerly known as the Chemin de Fer de l'Ouest, which was taken over by the general government some years ago and is operated by it as a state railway. The other concerns enjoy some measure of Government assistance in the way of advances or guarantees, in return for which they will become Government property in the course of time.

The main offices of these five systems are located in Paris, from which point the lines radiate to all parts of France, very much as the spokes of a wheel lead away

from the hub. Paris is, therefore, the nerve center of France as regards government, finance and control of transportation.

By mutual consent and a definitely adopted arrangement, specific sections of France are assigned to the above companies. There is scarcely any invasion of the territory served through one system by the lines of another, and even where adjacent divisions join, there is but little overlapping. Competition for traffic between the companies, therefore, does not exist. These arbitrary territorial divisions are wedge- or fan-shaped, with their small ends meeting at Paris.

The Etat covers that part of France lying west of a line beginning at Dieppe on the Channel and running through Paris, Orléans, Tours, Poitiers to Bordeaux. In consequence it serves the ports of Dieppe, Havre, Rouen, Cherbourg, Brest, St. Nazaire, Nantes, La Rochelle and Bordeaux.

The Paris-Orléans system, including the lines of the Chemin de Fer du Midi, lies east of a line commencing at Paris and passing via Châteaudun, Tours, Poitiers, Angouleme and Bordeaux to Biaritz and the Spanish frontier, thence north of the Pyrenees Mountains, and west of a line running from the Spanish frontier on the Mediterranean along the latter and through Montpellier, Nîmes, Clermont-Ferrand, Nevers to Paris, with branches on the west side from Tours, one to Le Mans, the other to Nantes, St. Nazaire and Brest. This latter branch is the only case of a line of one company invading to any appreciable extent the otherwise exclusive territory of another. The P-O company has no monopolistic control over any harbor except the small one of Bayonne near Biaritz, though it provides the main service to Bordeaux and carries the bulk of the traffic to and from that great port. On the other hand, the Etat is the sole railway running into Dieppe, Havre, Rouen, Cherbourg, and

La Rochelle, and is the principal line to Brest, St. Nazaire and Nantes.

The territory of the Paris-Lyon-Mediterranée lies east of that of the Paris-Orléans and is bounded on the west by a line marked by Paris, Nevers, Clermont-Ferrand, Nîmes, Montpellier, on the south by the shore of the Mediterranean, and on the east by the frontiers of Italy and Switzerland, and a line through Belfort, Is-sur-Tille, Dijon, Paris. While this system does not touch the Atlantic seaboard, it reaches the great Mediterranean port of Marseille and the naval base at Toulon. It provides the main lines of communication to Italy and Switzerland and connects the three largest cities of France, Paris, Lyon and Marseille.

The Chemin de Fer de l'Est serves eastern France as included between two lines running from Paris, one to the German frontier as it existed before the war in Alsace, the other to the eastern part of the Belgian frontier and Luxembourg. The first or southern of these lines, is marked by Paris, Troyes, Is-sur-Tille and Belfort, the northern one by Paris, Meaux, Soissons, Laon and Hirson. The Est is the only French railway company whose rails do not reach salt water. It furnished the sole lines to Germany and Luxembourg, the former via Metz and Strasbourg. It enjoyed a valuable traffic in minerals, especially iron ore and steel, and covered the great wine districts of Champagne and Burgundy.

The Nord system made a net work over the rich and highly important part of France lying between Paris, the northern channel ports and Belgium, an area bounded on the west by the tracks of the Chemin de Fer de l'Etat and on the east by those of the Est, as defined by the two radiating lines, Paris-Beauvais Tréport and Paris-Laon-Hirson. Within these boundaries, the smallest area belonging to anyone of the French railway companies, lay France's greatest coal fields, stretching from Arras

to the Belgian frontier; Lille, the fifth city of France; Calais and Boulogne, main ports for Anglo-continental traffic and the railways connecting Paris with Belgium and through Belgium with Holland and northwestern continental Europe.

From the above description of the routes of and the territories served by the several systems, it will be seen that the Nord and Est companies were the only ones whose rails reached the actual theatre of war, and of these the Nord was the one chiefly affected. Considerably more than one-half of the lines of this latter company were in enemy hands or turned over absolutely to the French or British military authorities for operation by them.

The second class of French railways consisted of disconnected lines under mutually unrelated ownership and operation with a gauge of one meter (3 feet 3 1/3 inches), their construction having been begun at a time when there existed a very mistaken but widespread belief in the economy of narrow-gauge railways. At the same period many miles were constructed in accordance with the same error in the United States, especially in the West, and notably in Colorado. These second-class railways were purely local concerns, in fact, they were officially described as " Chemins de Fer d'Intérêt Local " and were controlled by corporations in which the communes or municipalities adjacent to the lines were interested, frequently to the major extent. The lines of each separate company were usually short, rarely exceeding seventy-five miles for any one concern, though the total length for the whole country was about 5,600 miles. The traffic, consisting chiefly of passengers, was light, and, consequently, the indirect local accommodation usually exceeded in value the direct financial return to the owners, that is, the adjacent communes.

The variation in gauge between the first- and second-class railways was unfortunate for military purposes because, except in a very few instances, the metre gauge lines could not be used for military ends on account of their own lack of sufficient rolling stock and the undesirability of acquiring locomotives and cars that could not be used universally. These lines were, therefore, of little or no use at all when they lay in the zone of the armies, unless they could be reconstructed into standard gauge lines. This was a matter of some difficulty, as the old cross-ties would not answer and the rails were too light except for very restricted traffic. The other alternative was to convert them into narrow-gauge lines of the light railway or military gauge of 60 cm. Such change was readily accomplished by simply drawing the rails together and was nearly always done if the meter gauge railway, by its location, lent itself to being made a part of the army light railway system.

Exclusive of the meter gauge railways, the five great corporations, or six, if the Midi is regarded as a separate concern, comprised approximately 25,000 miles of main line with 10,800 miles of second tracks and, therefore, was in extent of mileage, the third largest system in Europe, being exceeded only by the railways of Germany (38,500 miles) and Russia (45,000 miles). In regard to volume of traffic the French lines again ranked third among European countries, coming next after the combined railways in the United Kingdom and of Germany in the order named.

The French lines can be fairly compared with the American railways composing what the Interstate Commerce Commission formerly described as Group II, or those approximately of the States of New York, Pennsylvania, New Jersey, Maryland and Delaware. This area in the United States includes the important lines such as the New York Central, between New York and Buffalo,

and the Pennsylvania, Baltimore and Ohio, between New York and Pittsburgh; the Jersey Central and Reading, all the Lackawanna lines, Erie and Lehigh Valley. These American railways were almost exactly of the same length as the combined French railways, and serving, as they did, the most densely populated and most highly productive portion of the United States, enjoyed the most intense traffic to be found in any section of the country. Although they constitute but about one-tenth of the whole railway mileage of the United States, they carry more than one-third of all the passengers and nearly one-third of all the freight. As to comparative traffic between the French railways and the American railways covered in Group II, the former carried passengers in the ratio of five to three, but freight tons in the ratio of only two to five. As French freight trains were shorter and passenger trains more frequent than similar American trains, the traffic units on French railways were run at much shorter intervals than ours, giving a more congested service and, consequently, presented serious difficulties to the introduction of a great number of additional trains, such as the entry of America into the war entailed.

Before the war French railways were in fine physical condition with heavy rails, stone ballast, complete block signals and permanent structures. There were run, especially on the Nord lines between Paris and Boulogne and Calais, some of the fastest trains to be found anywhere in the world. Although, through lack of new material and equipment and the great shortage of labor, it had been impossible to maintain these railways during the war at the previous standard of excellence, nevertheless the authorities had succeeded in keeping them in surprisingly good condition when all the attending circumstances are taken into account. In fact, when the Railway Commission travelled on the main line of the Est railway

in June, 1917, a speed of sixty to eighty miles an hour was made over a considerable distance.

As against the contingency of war, the French general staff had planned years ago, and with no particular war in mind, full provision for the most efficient method of operating the railways with the double view of military exigencies and existing commercial requirements. The employees on French railways were all subject by law to army mobilization, and were so mobilized in the late war. This mobilization, providing for holding skilled men at their posts and securing a permanent working staff, greatly facilitated control of the railways by the military authorities. The French army regulations ordered that, while the general officers of each railway corporation should continue to function and administer the properties in the event of war, and while the employees of all grades, whether mobilized or not, should remain at their posts to carry on their regular daily routine, a new controlling supervision, to last only during the emergency, should be established in which the imperative military needs and the civil demands could be examined, adjusted and both be satisfied.

This control consisted in chief of two commissioners or "Commissaires" to use the official title, one, the "Commissaire Militaire," being named by the War Department, the other by the company. These two officers worked side by side with equal authority, but with required joint action to be effective. They passed on and determined all matters of general principle, acquisition of equipment or permanent way material, decided on the necessity for and ordered the construction of new or additional lines, tracks, yards, storage places or other major facilities, placed maximum and minimum limits on trains to be run, made arrangements for the military service, and fixed the number of the working staff and their compensation. In short, they so ordered the workings

of the railway system as to permit the harmonizing to the fullest extent of the double function of serving the needs of the army and of the civil population.

It was impossible for these two commissioners to supervise all the minor details, so that under-commissioners were appointed for all places where there was any likelihood of clash between military and civil interests. Such places were terminal yards where surplus rolling stock was stored and trains made up, or regulating stations where trains were received with military supplies which, in some instances, were to be put in storage, in others to be forwarded to other stations with or without breaking bulk. It is obvious that at such points, questions would frequently arise as to whether it was more important to assign cars to contain a shipment of shells for the army or to carry a consignment of coal to some factory, or to what extent priority in schedule was to be given to troop trains over those with ordinary passengers. Such questions were dealt with by the under-commissioners who, like their chiefs, worked in pairs, representatives of the two services, with equal power and equal responsibility. These men investigated all such questions on the ground and, having ascertained the facts, were usually able, acting under general instructions handed down to them from time to time, to reconcile apparently conflicting demands. Should they be unable to agree or be unwilling to assume responsibility for a decision fraught with such importance as apparently, perhaps, to exceed their powers, the matter would be referred to higher authority for decision, the reference being accompanied by recommendations from the two duly charged military and civil representatives.

To an American accustomed to the principle of a single executive or unacquainted with European practice, such duality of control might seem dangerously complicated and be considered as apt to lead to frequent and

annoying deadlocks. But the European manager has been trained to it by long experience through a system of double signatures to bank cheques and letters, double approval for all orders, etc. He practically never acts alone as an American general manager usually does. Consequently the commissioners and under-commissioners had had previous experience in working alongside of a mate with joint and coequal powers and found little difficulty in producing results. In the French situation, both of each pair of men felt that they were working for France and, undoubtedly, faithfully endeavored to reach the best solution. There was no antagonistic feeling of the army versus the civilian nor jealousy of the former by the latter, because, although the representative of the latter might not be in military uniform, he was nevertheless mobilized and was, equally with his fellow, a soldier of France. Both realized that, while the army must be served promptly and served well, the civil industries must also be served, because on them the army depended for its supplies, and on these supplies rested the country's safety. They saw to it that a conflict between the two opposing demands was avoided, and that the service, whose needs were paramount at the time, was given priority.

One great advantage in this scheme (and so carefully studied and worked out in time of peace) for harmonizing the double functions was that it was quickly put in force without any disturbance of the existing operating machinery. When war was over, the working staff was demobilized, the chief and under-military commissioners were withdrawn and the operating staff of the railway company resumed its functions as a complete working unit without necessity for any reorganization. During the war nothing had been changed, nothing had been dislocated. There had been added, temporarily, certain special officials with equal but not superseding authority,

whose duty it was to see that the military requirements were understood and cared for properly but not to the detriment of the other obligations of the railway. When the necessity for such coöperation was passed, the officers were withdrawn.

France having been invaded and a considerable portion of the country and many miles of railway being in the hands of the enemy, there was a limit beyond which civil or commercial traffic ceased and there remained only the service of the combatant army. This line was the arbitrary demarkation between the Zone des Armées and the Zone de l'Intérieur. The Zone des Armées had an irregular width averaging about twenty miles. Within this zone the civil population was largely evacuated, but not entirely so. In particular districts, such as the coal mining country in the north, civilian life still existed well within shelling distance, even women and children continuing to remain at work in the mines. But once beyond the line of the Zone, all normal civil railway traffic ceased. There were no tickets to be had, nor time tables to be consulted. All trains were handled by the military authorities, and all movements were subservient to army demands. Such civil traffic as might exist within the forward zone was of secondary importance.

The general control of all railways in the Zone des Armées was under the charge of an officer stationed at General Headquarters. In the event of an advance being made that could be considered permanent, the limitations of the Zone des Armées would be moved forward. At this new limit the exclusive military control would cease and the authority of the railway companies through the joint commissioners be established.

As there was a single officer at the French General Headquarters controlling army railway operation, so there was a single officer in the War Department in the Boulevard St. Germain, Paris, acting as the liaison

officer or connecting channel between the Commissaires Militaires and the chief military authority. The personal machine was, therefore, complete. Any disputes between those high in authority were adjusted by a responsible officer of the Government, a member of the Cabinet, who also in the name of the Government arranged for purchases of railway material and saw to it that the available supply of material and labor was distributed among the five companies according to their actual and most pressing needs. This official was the Sous Secretaire des Transports, ranking as a cabinet member without portfolio, but under the Minister of Public Works. At the time of America's entry into the war, this post was ably filled by Monsieur Albert Claveille, an engineer by profession, formerly general manager of the Chemin de Fer de l'Etat. Subsequently, M. Claveille became Minister of Public Works in the Ministry of Painlevé. He retained this portfolio through the following ministry of Clémenceau until after hostilities had ceased.

A picture of the French railway system and its wartime management is necessary to permit an understanding of the structure that was to be so essential to the successful American participation and on which the special American service was to be grafted.

Of the five railway companies, only two, as was said above, reached the actual battle front. The British operations were confined wholly to certain parts of the Nord lines except for the men and supplies that entered through Dieppe, Havre, or Rouen, and who made the initial stage of their journey on the rails of the Etat company. On the other hand, the Est lines running towards Soissons, Château-Thierry, Verdun, the Valley of the Meuse, St. Mihiel, Toul and Nancy, were the lines of communication serving the American front. The American troops, with their supplies, were landed at the several ports from Brest southward, whence they were trans-

ported over the Etat or P-O lines and across those of the Paris-Lyon-Mediterranée to reach the Chemin de Fer de l'Est. American railway movements came, therefore, in contact with four of the five main systems, and as the principal traffic currents of these concerns flowed towards Paris, the American routes ran transverse to this established order, which introduced additional complications in operation.

CHAPTER VII

AMERICAN RAILWAY OPERATIONS IN FRANCE

When the staff took up the question of organizing a transportation system for the American Expeditionary Forces in France, it had the benefit of British experience. The latter had been obliged to do as evidently Americans would be forced to do, to modify opinions as to methods of railway operation in order to meet French views, to adapt themselves to existing conditions that could not be changed, and to learn how to manage a system of railways burdened with military demands that must be met promptly and at the same time with a local civilian traffic that could not be ignored. But they had found a satisfactory solution.

During the first year of the war, Great Britain handled its traffic over French railways without any well-established organization or definite plan for coöperation with the French. But as the army grew in size, as the amount of supplies increased in tonnage, and as the French became more and more in need of assistance, the British realized the necessity of constructing a well-designed operating machine whereby their men and materials could be handled with the maximum of certainty and the minimum of friction. For this task, Mr. Eric Geddes was selected, sent to France and given the rank of major-general that he might have proper authority.

Mr. Geddes, or the Rt. Hon. Sir Eric Geddes, K. C. B., as he afterwards became, was one of the human features of the war. Born in 1876, he passed some years in the United States in railway service, chiefly on the Baltimore and Ohio Railroad. After some extended experience in India, he returned to England and became General Man-

ager of the North Eastern Railway. Early in 1917, Major-General Sir Eric Geddes was recalled as chief of transportation in France, placed in charge of hastening ship construction in England and created Vice-Admiral. He, therefore, had the unique distinction of a civilian holding at the same time temporary rank as Major-General and Vice-Admiral in the British army and navy respectively. Before the war came to an end, Sir Eric Geddes was appointed First Lord of the Admiralty, an office corresponding to the Secretary of the Navy in the United States. He was succeeded in France by his previous deputy, Major-General Sir P. A. M. Nash, who before the war had been Locomotive Engineer of the Great Northern Railway of England, and to whom the A. E. F. owe many courtesies.

Major-General Geddes was given command of all transportation matters in France with the title of Director General of Transportation, or D. G. T., as it was always mentioned. The organization that he built up embraced every channel for transportation, including standard gauge railways, light military railways, canals and roads, their construction, maintenance, and operation, and the authority of the Director General of Transportation extended unbroken and unchallenged, except as it had to conform to military exigencies, over the whole of France wherever British operations were paramount. To the British transportation department there was no line separating the Zone of the Advance from the Zone of the Rear as there was in the French and later in the American service, nor was there any conflict in authority between the several branches of transportation, because they all reported to one head. The only exception was the control of the transport vehicles, motor and horse, used on highways.

The organization thus created consisted in chief of five directorates, reporting to the Director General of Trans-

portation, but exercising separate authority over transportation, light railways, roads, inland water transport and docks. There were three technical departments whose chiefs, with the titles of Chief Railway Construction Engineer, Chief Mechanical Engineer and Chief Engineer of Port Construction, while reporting direct to the Director General of Transportation, coöperated with the several "Directors" and carried out the necessary railway or mechanical construction in their several departments. In addition there were appropriate sections dealing with questions of organization, statistics, stores and accounts, while the Canadian Railway troops maintained a section of their own, more fully described in Chapter XXV.

Liaison with army commanders was maintained through two Deputy Directors General of Transportation, between whom the five armies, that composed the British Expeditionary Force, were divided into two groups and under whom were Assistant Directors General of Transportation, one for each army. It was the duty of the latter, having ascertained army needs and learned of proposed movements, to report on the same through the Deputy Director of the army group to the Director General who made the necessary provision through the Directors having supervision. In the event of any difference of opinion between the Director General and an army commander final decision was rendered nominally by the Commander-in-Chief, but in practise by the Quartermaster General acting in his name.

The authority of the Director General was confined strictly to France. Vessels arriving at French ports were discharged by a staff working under officials of the admiralty, but once the cargo was placed on the quay and freed from the ship's tackle, it became the charge of the Transportation Department and so remained in its passage through the storage depots until finally consumed by men or guns.

The headquarters of the Transportation Department were established in the Château Monthuis, quite close to Montreuil, in whose charming park the office buildings and quarters for the headquarters staff were erected. The General Headquarters of the British Army were located in Montreuil, the delightfully quaint old city with its medieval walls and moat perched high on a hill overlooking the valley of the Nocq. To the west was the sea, at Etaples only ten miles away, while not much further to the south was the historic field of Crecy. The Director General was thus in close touch with the center of military activity, and was conveniently located to reach quickly any point on the British front and the ports of Dunkerque, Calais and Boulogne.

Montreuil was never referred to by name, but always as "G. H. Q." There was the fiction that somehow the enemy did not know where the British headquarters were located, and they would never know if only everyone would refrain from mentioning the name of the place. Of course, they did know, but it was a singular fact that Montreuil was never bombed. It was said, but probably with as much truth as many other things, that the Germans avoided bombing Montreuil through the personal orders of the Kaiser, who hoped that in return the British would avoid bombing his own headquarters in the field. In this matter of mentioning names, Americans were not quite so particular, for although Chaumont was generally spoken of as "G. H. Q.," the fact that there were two main points, Chaumont and Tours, the headquarters of the Army and headquarters of the Service of Supplies, led unavoidably to the speaking of both places by name.

The American Transportation Department was patterned on the British experience as a model, and in the early planning, practically all the work was done by Major W. J. Wilgus, the sole member of the first engi-

neer commission who was not assigned to other duties as were the other members. It was no light task that faced the Staff. The investigations of the Commission showed the transcendent importance of transportation. But neither the system nor its component parts were in existence and much time would obviously be needed to manufacture and ship the rails, the rolling stock and the other required matériel. Orders, therefore, must be placed at once if the equipment were to be on hand when needed. The nature of the equipment depended in large measure upon the size of the American army, its composition and the sector it was to occupy, and in June, 1917, no one of these fundamental details had been determined. However, in spite of difficulties, a requisition for matériel was drawn up and cabled to Washington in July.

The skeleton plan on which this requisition was based contemplated, as suggested by the Staff, a possible initial American sector between Epinal and Nancy, which could be served by the existing double-track railway lines from Bordeaux and St. Nazaire, meeting at Bourges. From this point there was a railway capable of handling 25,000 tons of supplies daily, with supplementary lines having sufficient capacity over local requirements of 25,000 tons more. Beyond a daily tonnage of 50,000 tons it was not possible to see.

It was recognized that the additional burden on the French railways would require, on the part of the American Army, the construction of new yards, water supplies, engine terminals and other facilities that responsibilities of this kind entail, and also the construction of many other additions such as extra tracks, cut-offs, and regulating stations, all with the view of removing any special restrictions that might hamper the maximum train movements. In addition, but fortunately this was one of the few questions whose answer could be postponed, was the collecting of ample equipment of

all kinds for reconstructing railways in the enemy's territory when the movement towards Berlin should begin.

The requisition covered not only sufficient rolling stock and track matériel, but the necessary railway operating personnel for the above traffic, on the assumption that the A. E. F. would work its own locomotives and cars by American train crews in transporting its supplies from the ports of entry to the front, but subject to the operating rules in force on the French railways. The handling of American traffic to as large an extent as possible under American control was held as absolutely necessary, as otherwise the success of the American armies might be jeopardized should the French supply of personnel and equipment fall short of needs at a critical moment.

In carrying out a comprehensive plan of this kind, one of the first questions arising was the character of the rolling stock to be used on the French railways. A decision was reached that the locomotives should, if practicable, be in accord with the American practice and have a traction force that would be limited only by the structural clearances of the French railways and the supporting strength of the bridges. It was decided also that the cars should be of the American type with a capacity consistent with the same limitations as for locomotives and equipped with air brakes, but with the French type of couplers and buffers instead of corresponding American devices. The outcome of these decisions on equipment was that the Transportation Department was furnished with consolidation locomotives with a tractive effort of 36,000 pounds and cars of thirty tons' capacity. Thus the policy adopted in the early days of the Transportation Department, then a function of the Chief Engineer, contemplated and finally permitted the A. E. F. to run its own trains made up of American locomotives and cars and manned by American personnel under "track-

age rights " over French railways from the sea to the front, a distance of about 600 miles, by the several routes.

Immediately after sending the requisition for matériel, the Commander-in-Chief cabled to the Secretary of War that an extensive study of the transportation methods of the Allies had convinced him that the operation of the railways must be under a man with large experience in managing commercial railways in the United States. He asked that the ablest American railway man available be sent to him, explaining that, after the unfortunate results with inexperienced men, the British had selected the best executive man they could find to have charge of transportation, and that the question was mostly one of operation and management in intimate relation with the French who would retain general control over their own commercial transportation.

Acting on the recommendation of the Commander-in-Chief, the Secretary of War sent over Mr. W. W. Atterbury, Vice-President in charge of operations of the Pennsylvania Railroad.

On September 14, 1917, the Transportation Department was established by General Order 37, G. H. Q., 1917, and thereby became one of the technical services of General Headquarters. This G. O. ordained that:

1. A Transportation Department is hereby established as one of the technical services of the Headquarters, A. E. F. This department will be charged with the operation, maintenance and construction of all railways and canals under American control and with the construction and maintenance of wharves and roads, and of shops and other buildings for railway purposes. Until such time as the number of construction troops in France warrants a division of engineer troops and labor between the Lines of Communication and the Transportation Department, all construction work will be done under the Commanding General of the Lines of Communication.

The Chief of the Transportation Department will be the Director General of Transportation and will be assisted by the following staff:

a. Deputy Director.
b. Engineer of Construction.
c. Manager of Light Railways.
d. Manager of Roads.
e. Business Manager.
f. General Manager.
g. Deputy Director with each Army Commander.

The Deputy Director (personal) will be the personal representative of the D. G. T. and will act for him in his absence. The Deputy Director in each of the army groups will be the representative of the D. G. T. with the Army Commander; will be responsible for keeping the D. G. T. advised of transportation requirements within his area; and, in an emergency, shall act with the authority of the D. G. T.

The General Manager will be responsible for operation and maintenance of all broad gauge lines, including equipment and terminals. He shall be assisted by:

a. General Superintendent.
b. General Superintendent of Motive Power.
c. Engineer of Maintenance of Way.
d. Superintendent of Transportation.
e. Superintendent of Railway Telegraphs.

The Business Manager will be responsible for purchases, supplies, stores (unless on line, in which event they are under the Division Superintendent), accounts, statistics and disbursements. He shall be assisted by:

a. Purchasing Agent.
b. Chief Accountant.
c. Chief of Bureau of Claims.
d. Statistician.
e. Treasurer.

The Engineer of Construction will be responsible for construction of new lines (broad gauge), terminals, docks, shops, sheds, buildings and other structures connected with railways.

The Manager of Roads will be responsible for maintenance of existing highways, reconstruction and construction of new highways within the zone of the armies occupied by our forces.

The Manager of Light Railways will be responsible for construction, operation and maintenance of all light railways for use of our forces.

The same order named Mr. Atterbury as Director General of Transportation, Major (subsequently Colonel) Wilgus as Deputy D. G. T., Brigadier-General William C. Langfitt as Manager of Light Railways, and Brigadier-General Charles H. McKinstry as Manager of Roads. On October 8th Mr. Atterbury was made a Brigadier-General.

The early days in the history of the Transportation Department were not particularly cheerful. The Director General was confronted with the difficulty of arranging for operating trains over lines not then adequate to sustain the double burden of French commercial and American army needs, lines that had been developed in accordance with principles and were being worked by methods diametrically opposed to those in vogue on the railways in the United States, whose staff spoke a different language, and of adjusting the principles of American railroad operation to an established military system whose officers had been educated along quite different lines.

When the burden of work of the Commander-in-Chief began to assume huge proportions, it was deemed advisable to relieve him of all unnecessary details, so that on February 16, 1918, there was issued General Order 31, creating the Service of Supplies, wherein the Department of Transportation was made a section of the Service of

Utilities, the latter being one of the main component parts of the Service of Supplies.

Transportation was found to be too important to be left as a branch of a department, even though charge of railway construction had been taken from the Director General and given to the Director of Construction and Forestry in March, 1918. Consequently the Service of Utilities was abolished by G. O. 114, July 11, 1918, and the Department of Transportation substituted therefor, thus permitting the D. G. T. to report directly to the Commanding Gèneral, Service of Supplies. As thus constituted, the Transportation Department covered:

Operation and maintenance of all railways and canals, under American control.

Operation of inland water transport and ocean transport with England and other European countries.

Compilation of accounts due the United States for material furnished the French railways.

Compilation of statistics showing classified tonnage received at ports; that moved over railways; and that delivered at rail heads.

Operation of terminals, including unloading of ships, and transportation of goods to storehouses.

Procurement of railway supplies.

Control of telephones and telegraphs for railway purposes.

Railway personnel.

Control and maintenance of all rolling stock and motor cars.

Disbursement incident to performance of foregoing duties.

Some difficulties were found in adjusting military organization to the operating organization of a commercial railway whose functions were the moving of men and material from one point to another. In the latter organization, the ordinary regimental unit did not fit.

Finally it became apparent that the best solution was the creation of a transportation corps wherein the structure of an infantry regiment, the base of all military units, could be dropped and men formed in such categories as would be best adapted for railway operation. To this end the approval of the War Department was secured and the necessary orders were issued just as hostilities ceased. The organization that was contemplated consisted of 6,000 officers of various ranks and 200,000 enlisted men, although on November 11th the actual number of individuals in the corps was 1,677 officers and 61,894 enlisted men, the largest technical service in the A. E. F.

American railway operation in France can be divided into three phases.

The first phase covers the period from 1917 to the spring of 1918 when the A. E. F. was in the position of a large shipper, all its troops and freight being moved by French equipment with French train crews exclusively.

During the second phase which continued from the spring of 1918 until November of the same year, when the American army operated its own terminals with its own rolling stock and men, and by means of its own engines, cars and men gave to the French substantial aid in a steadily increasing degree in handling traffic on the railways.

At the conclusion of hostilities the third phase was just beginning, for it was then arranged to take over certain definite sections of French railways and work them with American personnel and under the American system of train operation.

To supervise operation, the Director General of Transportation appointed a General Manager under whom were a Superintendent of Motive Power and a General Superintendent of Transportation.

As was fully explained when discussing French rail-

ways, the systems with which Americans came in contact were the Etat, the Paris-Orléans and Midi, the Paris-Lyons-Mediterranée and the Est. The first two of which extended easterly from the several ports of entry between Brest and Bordeaux, and converged to places in the center of France, east of Tours and south of Orléans, where there were established the principal intermediate supply depots and the great aviation camps. From the points of convergence, other lines radiated to the regulating stations of Is-sur-Tille, Liffol-le-Grand and St. Dizier and beyond to all points in the American sector. The total length of French railways used by American traffic was about 5,000 miles.

These lines, or such portions of them within the limits of the Service of Supplies as carried American shipments, were divided for operating purposes into six Grand Divisions, and these were further subdivided. Each of the former was under the charge of a General Superintendent reporting to the Superintendent of Transportation, and each division under a Division Superintendent who, reporting to the General Superintendent of the Grand Division, exercised supervision over the American train crews coöperating with the French, had charge of repairs to American equipment, and did what he could to expedite American shipments in French hands. All these officials had military rank.

This organization was established only in the territory behind the regulating stations. Matters connected with transportation in the advanced section were, at first, largely under the control of the regulating officers appointed by General Headquarters, although an Assistant General Manager for the Zone of Advance, was appointed and attached to the Assistant Chief of Staff, G. 4 at G. H. Q., to assist in the transportation problems in that territory. Later, when it became apparent that the transportation problems in the Zone of Advance were

becoming more difficult, the Director General was requested to place a Deputy at General Headquarters. Subsequently, a similar organization to that which obtained in the Service of Supplies was formed and placed in effect in the advanced section.

In May and June, 1918, five battalions of railway men were assembled in France, the troops being selected at the classification camps at St. Aignan and Blois from the combatant regiments. They composed the first American operating unit. They were assembled at several points and for thirty days were instructed in French train operation by representatives of the French railways. Miniature signals were made and classes held at the camps in order to familiarize the men with signal operations. A résumé of the rules of the several lines over which the Americans were to operate was translated from the French and published in standard book form. The book contained the essential rules for French railway operation, showing the signal aspects in colors. As soon as the period of instruction was finished, the men were turned over to the French and used as much as possible to drive American locomotives which had begun to arrive and which were being used by the French to haul American freight.

The increasing number of American troops had put a tremendous burden on the French railways. At the end of May the amount of freight unloaded at the ports exceeded 25,000 tons a day. To relieve still further the transport situation, a request was made by Marshal Foch that railway troops from the United States be given priority and that 24,500 railroad men be sent over during June and July. Although this program was not fully realized, about 15,000 operating men did arrive in France before the end of July, and immediate steps were taken to instruct them and put them into service. Meanwhile, engine houses were being erected as fast as possible and

the sufficiency of the water supply was being investigated with the view to future extended operations. Because of the need of thirty days' instruction for the men, it was not until September that the first trains, operated entirely by American crews, began to run from the coast to the regulating stations.

It was agreed that Americans should operate their own trains so far as possible, the same to be made up at the ports and run through unbroken to the American inland terminal points. Wherever it was possible, no American trains were handled in French yards, as these were already congested and could not take care of additional traffic.

Freight runs were, therefore, made on the main line from Montoir to Saumur, from Saumur to Gievres, from Gievres to Marcy, and from Marcy to Is-sur-Tille, thereby obviating the use of the French yards at Angers, St. Pierre des Corps (Tours), Vierzon, Nevers and Dijon.

Although this kept French yards from being further congested, some difficulty arose by reason of the fact that the runs of the French pilots, one of whom was on every American train as conductor, did not coincide with the regular French train runs. The lack of through communications from the American yards to French yards, added other complications and it was frequently difficult to arrange for "marches" for American trains after they were made up in American yards.

The chief difference between the American and French railway operation was that of centralized control in the case of Americans and local control in the case of the French.

Before an international system of train working could be put on a satisfactory basis, it was seen that a new method of communication would have to be established over our lines, as the French system of telegraph and telephone, running only from station to station, could

not meet the needs of the American service. A selector telephone system was, therefore, installed from St. Nazaire to Is-sur-Tille, from Bourges to St. Florentin and Liffol-le-Grand, and from Bordeaux to Bourges and Vierzon. The line was cut at each division terminal so that operation of trains over any given division was under the control of a Chief Train Dispatcher at that point. In addition to the selector telephones, telegraphic communication was also established on all lines over which American trains were operated. This telephone-telegraph service proved efficacious, and, in fact, better communication was afforded on the lines operated by the Transportation Corps in France than on many good railways in the United States.

The French Chef de Gare or Station Master has absolute control over the movement of all trains through his station, and no train is permitted to depart without his consent. The Chefs de Gare are, therefore, a series of independent train control authorities, each one supreme in his own territory with no superior authority corresponding to the American train dispatcher. The trains are run on a series of schedules or "marches," beginning at one minute after midnight. The "marches" of trains in the direction of Paris are even numbered, those in the opposite direction odd numbered, and are arbitrarily spaced twenty minutes apart throughout the entire twenty-four hours. Therefore, on a double-track railway seventy-two trains per day in each direction is the limit of the traffic that can be handled. As a matter of actual practise, this limit is never reached on account of road delays, terminal congestions, etc.

On French railways all runs for trains and engine crews are turn-around runs, the crew starting from its home terminal and returning at the end of the day. The system of putting crews on rest at an outlying point,

common in American practise, is entirely unknown in France. Trains are blocked from station to station, all signals being under manual control, and with the exception of certain distant signals, no permissive signals exist.

The French rolling stock is very light and air-brake equipment on freight cars was almost unknown before the advent of American-constructed cars. The average French car has a capacity of about ten tons, while the American cars used in France had a capacity of thirty tons.

The French locomotives are of good design and construction, well adapted to the needs of that country under ordinary conditions. They are lighter than the locomotives generally used in the United States. In France a higher average speed is maintained and shorter and lighter trains are hauled than on American railways.

On account of the ordinary French freight cars being entirely without air brakes and that a great many of them were not even equipped with hand brakes, it was necessary to place a certain number of brake cars in each freight train, the number varying on the different railways according to the gradients and the length of trains hauled.

Owing to a fairly even balance of traffic in pre-war days, no central system of car distribution had been found to be necessary, the Chefs de Gare generally having enough empty cars at their stations to take care of local needs. If not enough cars were available, request was made on the nearest divisional terminal for the required number. The same lack of central coördination existed in respect to the distribution of locomotives, and no definite system was in force for the balancing of motive power along the lines. Such matters were left to the station masters.

It was believed that American trains could be

run more safely and more economically if operated with air brakes, but this was forbidden by French operating practise. However, as a result of a conference with the French railway officials and representatives of the Fourth Bureau of the French War Department, it was agreed that a test train should be run. Air brakes were used throughout and as a result the French operating representatives were convinced that the plan was entirely feasible. A second test train was run on another part of the railways assigned to American use, and it also was convincing to the French officials. In compliance with their recommendations, the Minister of Public Works issued an order authorizing the operation of American trains with air brakes over any portion of the American lines of communication.

In case that the American trains were made up partly of American and partly of French equipment, it was agreed that where such combining of equipment occurred, the French cars were to be placed behind the American.

Another point which involved extended discussion was that of tonnage rating, the French officials claiming that the American tonnage ratings were much too high, and that we would not be able to accomplish what had been planned. A thorough survey of the lines was made, and it was found that the French in computing their tonnage ratings used a greater margin of safety than is common in American practise, and that in the main their ratings more nearly approximated the facts than our own. American trains were limited to a length of not exceeding 500 meters, including the locomotive, but this limitation was not due to the type of motive power used, but to the length of passing sidings on the French railways.

Many of these questions might easily have led to serious differences. That they were all adjusted was due to the tact, courtesy and accommodating character of the French officials.

Until some time after the signing of the armistice the actual operations of troop trains were conducted almost entirely by the French, although in some cases American equipment and American crews were used. The troop trains, however, were run between French terminals and not between American terminals, as was the case with freight trains.

One of the most serious problems in the transportation of troops was the prevention of personal injury. The accident ratio among troops travelling over American lines of communication was very high. During the warm weather the temptation was great for soldiers to get out of the cars in which they were crowded and to ride between them or on top, or to sit in the doors of box cars, with their heads and legs projecting. The clearance between cars and bridges and tunnels on the French railways is considerably less than similar clearances in the United States. To attempt to lessen the consequent frequent occurrence of accidents, an active campaign was started by the Transportation Service in the shape of posters and warning notices which were distributed among the troops at points of entrainment. But the average American was incorrigible, apparently it is only death that stops him. In spite of all warnings, notices and orders, in spite even of the many fatal accidents, it was impossible to prevent the practice. The men would take the chance.

For the transportation of sick and wounded, the Transportation Department ordered ambulance trains to be built in England after the standard British plans. Nineteen such trains with a total of 304 cars were delivered, and twenty-nine more trains were under construction or ordered when the war ended. These trains were composed of cars with two tiers of iron beds very comfortably arranged, a car divided into an operating room and dispensary, kitchen and din-

ing car, and cars for all kinds of supplies and quarters for doctors, nurses and attendants. When war broke out in 1914, there were no such trains in existence and arrangements had to be improvised out of any cars at hand. The British trains were models of completeness, comfort and general excellence of design.

A distinctive feature of the railway organization in France was the establishment of the Railway Transport Officer or R. T. O. Service. This system was patterned after the one in use in the British army where specially trained officers, " R. T. O.'s " were placed at the more important freight and passenger stations to keep watch on freight movements and to aid other officers and men when travelling. The difference in language made it very difficult for the travelers to get information regarding train schedules and the handling of baggage and freight. The Transport Officers were installed both with the view to assist them, and incidentally to relieve the French from the burden of dealing with a great number of passengers unfamiliar with the language and customs of France.

Effort was made to secure for this purpose officers who had had railway experience and who, whenever possible, possessed some knowledge of the French language. Such officers as it was possible to select were sent to a school where they were instructed in French railway methods and the manner in which shipment of troops and freight was made. There was a total of about 220 of these officers stationed at the more important stations and terminals. The Railway Transport Officers were not confined to the main lines of communication, but were to be found all over France in leave areas or at important junctions, and even in England and Italy. If an " R. T. O." was efficient and possessed tact with patience, he was an important member of the army and a very helpful friend to his fellow-soldiers.

CHAPTER VIII

STORAGE YARDS AND OTHER RAILWAY CONSTRUCTION

Ports were needed for the landing of men and supplies, and railways were needed for their transportation, but all the ports and all the railways would have been worthless if provision had not also been made for the housing of the men and the storage of materials. The men were not difficult to handle, although barracks with a floor area of 250 acres had to be erected. Men can go almost anywhere and take care of themselves. They soon learned that they would not see again, until their return to the United States, anything approaching in completeness and comfort the camps they occupied during their period of training at home, and ceased complaining of hardships. It was the mass of inanimate objects of all sizes, shapes, weight and composition that caused official concern. This dead freight had to be cared for, and carefully, from the moment of discharge from ship until that of actual consumption.

At the outset the Commander-in-Chief laid down the rule that sufficient supplies of all kinds to maintain the army for ninety days must be kept on hand. He suggested that this quantity might be distributed among three points. Following this suggestion it was decided that supplies enough for forty-five days were to remain at a base storage, for thirty days at some intermediate point, and for fifteen days in the advanced area.

Storage facilities for army supplies were of three classes. The first was open storage, where imperishable articles such as pipe, pig metal, coal, lumber, etc., could be kept, which required but the necessary area of land with convenient tracks to permit cars to be unloaded and

again loaded. The second was also open, but tarpaulin covers were used to protect such articles as hay, canned goods, small arms in boxes, and ammunition. The third was covered storage as afforded by buildings for the various things that exposure to dampness would injure. It is the last which caused most worry, for both forms of open storage were easily and quickly arranged.

It was at first estimated that to house ninety days' supply per man there would be required an average of twenty-one square feet of covered floor area. As the storage building unit was fixed at a width of fifty feet, this average meant that, when an army of 4,000,000 men were in France, warehouses would be needed equivalent to one building thirty-two miles long. Fortunately, this estimate was proved to be unnecessarily generous, as it was found that more and more goods could be kept quite safely under the sole and simple protection of a tarpaulin. In consequence, the lesser standard of ten square feet of covered storage area per man was adopted. But the demand for men was so great following the German offensives of the spring of 1918 that all available vessel space was given to troops at the expense of supplies, so that a sufficiency to carry the army for ninety days was never on hand. During 1918 the minimum was enough for twenty-three days during January, and the maximum for seventy-two days during June, when new ships of the emergency fleet began to become effective. There was an average of fifty days' supply from January to November. In the meanwhile the requirement to hold a minimum of ninety days' supply had been reduced to forty-five days.

There was a tremendous number of storage places located, literally speaking, all over France. There were, first, the warehouses and open storage spaces forming a part of the wharf construction, where the cargoes were housed or placed when discharged from the steamers and while waiting transhipment to interior points. It was

too slow a process and one involving too much delay in freeing vessels to transfer directly from ship to car as a regular proceeding.

Next in order came the base depots, huge affairs covering, as will be seen presently, areas whose boundaries could be stated in miles. These depots were located as close as could be arranged to the ports that they served, and to them were taken the supplies from the wharves and wharf warehouses as fast as they could be handled. This prevented congestion on the wharves. At the base depots the supplies were sorted systematically, similar kinds of articles being put by themselves. Ships' cargoes were often badly mixed in loading, so that sorting and segregation were necessary after discharge in France.

The base depots were the main reservoirs. They were too far from the front to be relied on for quick service in case of emergency. Intermediate depots were, therefore, constructed, about midway between the coast and the front, which rivalled in size some of the base depots and where enough supplies could be stored, either under or without roof, to carry the combatant army for, perhaps, twenty days. Such a figure is stated in general terms. Of some classes of articles there was usually a generous surplus, while of others there was always a shortage, but of such supplies as there were on hand, a successful effort was made to keep a substantial amount at the intermediate depots.

The intermediate depots were located in the interior of France, away from the coast and frontier, beyond the congested districts next to the seaports, where serious train delays were frequent, delays that frequently and seriously interrupted a steady forward delivery. On the other hand, they were sufficiently far back from the fighting front so as not to be exposed to easy airplane attack or be threatened by an enemy advance, and yet sufficiently near to the front that supplies might be sent

to the army zone by motor truck in case of urgent call, which sometimes happened.

Next to the intermediate depots, and third in the chain, came the regulating stations, where shipments were received in train loads from either the base or the intermediate depots. The regulating stations, while extensive, were simple when compared with the other depots. They consisted of yard tracks where cars of incoming trains could be sorted according to ultimate destination. Covered and open storage facilities were provided where supplies could be held if the forward depots or "dumps" were full. The regulating stations were in the advanced area and, though perhaps beyond the reach of shells, were nevertheless likely to be bombed. It was, therefore, not desirable to hold at such points more supplies than necessary to furnish a small balancing reservoir.

Beyond the regulating stations were the advanced or army dumps at the rail-heads where the minimum amount of supplies was stored. There were, therefore, four steps in the progress of materials from the coast to the front trench. It was not necessary that every article should pass through each depot. The base and intermediate depots were nothing but huge reservoirs holding the surplus. If there was a demand at the front for certain articles, shipments could be made direct from the wharves to the nearest regulating stations, cutting out the base and intermediate depots entirely, or a draught might be made on either one of the last two.

There are neither words nor statistics that will enable one to see in his mind's eye one of these great depots. When the units of measure are hundreds of miles for the railway tracks, acres for the floor area of buildings, and square miles for the extent of land, it is quite impossible to picture the scene, with the puffing locomotives, long strings of loaded freight cars, piles of every imaginable

kind of merchandise and the operating force in uniform under military discipline. There is no single railway terminal in the United States that equals in capacity for the handling and storage of goods, any one of several of the American army depots in France.

The interlocked system of port, base and intermediate depots, with the regulating stations, forward dumps and their various component parts, was not a single creation. It represented the joint action of many boards of engineers. In fact, not only had the end not been reached but plans for still further increases were being considered when the cessation of hostilities in November, 1918, put an end to all development.

The first step in the matter of storage yards was taken by the French early in the summer of 1917, prior to the organization of the Transportation Department, by fixing on the site for the yard of a regulating station at the junction of the Paris-Lyon-Mediterranée and the Est Railways near Is-sur-Tille, in the department of Côte d'Or, about sixteen miles north of Dijon. They made this selection as giving the best location for a regulating station, assuming that the American sector would be in the neighborhood of Toul, which it finally was.

The French engineers prepared plans for the depot and submitted them to the American Chief Engineer in August, 1917. The French plans were not suitable for American methods of operation and had to be completely revised by the Transportation Department. The American plans, work on which was begun in the autumn of 1917, contemplated the occupation of 840 acres with ninety-five miles of tracks, sixty warehouses providing 1,847,000 square feet of storage area, and open storage amounting to more than 5,000,000 square feet or 125 acres, nearly all of which was finished and put in use.

In August, 1917, the Fifteenth, Seventeenth and Eighteenth Engineers were in France. They provided a

AN AMERICAN ARMY STORAGE DEPOT IN FRANCE

skilled force capable of investigating, planning and executing on a large scale. Concurrently with making decisions as to the use of existing ports and the creating of new ones, determination as to the location of certain main depots was reached and their construction put in hand. While that work was in progress, studies were continued as to other projects. The sites selected for immediate occupation were St. Sulpice and Montoir as base depots for the several landing places in the vicinity of Bordeaux and St. Nazaire respectively, and Gievres as an intermediate depot.

St. Sulpice is located about nine miles east of Bassens. The site was acquired in 1917, the French Government using its powers of expropriation to secure the land either by lease or purchase. Such coöperation on the part of the French Government was, of course, always forthcoming. Plans were at once adopted contemplating 147 miles of track, 144 warehouses with a covered storage area of 2,263,000 square feet and open storage amounting to nearly 7,000,000 square feet. This layout had a length of about two and one-half miles, covering approximately 850 acres. By November, 1918, more than the originally contemplated covered storage area facilities had been constructed, with ninety-one miles of track and approximately one-half of the open storage area put in use. St. Sulpice itself was reinforced by the extensive warehouses along the wharves of Bassens, where much material could be held pending its shipment to the main base depot.

After extended and intensive study of the whole question of the most efficient development of the estuary of the Loire River, it was finally decided to place the base storage depot at Montoir, on the north bank of the river. This was a convenient location to serve both St. Nazaire and also the new wharves which it was proposed to build adjacent to Montoir. The plans finally developed for the

Montoir depot provided for 236 miles of track, 180 warehouses with 4,125,000 square feet and approximately 10,000,000 square feet of open storage. The construction of this yard was continued until the signing of the armistice, when considerably more than one-half of the original plan had been completed. The ground covered by the Montoir development was about two and one-half miles long and had an area of 1,200 acres.

Ranking in importance with St. Sulpice and Montoir were the two intermediate depots at Gievres and Montierchaume. The first site selected for a main intermediate depot was Gievres in the department of Loir et Cher, a point on the Paris-Orléans Railway, east of Tours and south of Orléans. The reasons for the selection of Gievres were: Firstly, it was located in a broad sandy plain where there was but a small local population to inconvenience and the maximum of topographical facility for extended construction was afforded; secondly, it was reached by direct rail communication, 208 miles long from St. Nazaire, which had been decided upon as the first point of arrival for American freight. No less than 2,600 acres of land were obtained in August, 1917, and a plan adopted contemplating 264 miles of track, 195 warehouses, aggregating 4,410,000 square feet of covered storage and 10,370,000 square feet of open storage, making it the largest depot of the American Expeditionary Force in France. By the autumn of 1918 one-half of the track mileage had been completed and about 3,600,000 square feet of the covered storage, and 6,000,000 square feet of the open storage put into service. This work at Gievres was begun by the Fifteenth Engineers, the first of the original regiments to arrive in France, who made all the preliminary surveys and plans.

Gievres was conveniently located, with direct communication with the ports on the Loire River and also with Brest. It was necessary, however,

that a complementary depot should be constructed with similar direct-rail communication with Bordeaux and the ports south of St. Nazaire. For this purpose a site was chosen in August, 1917, at Montierchaume, near the city of Châteauroux, in the department of Indre, thirty-five miles south of Gievres and 227 miles from Bassens. The plans for Montierchaume were drawn on a scale quite similar to those at Gievres, as it was contemplated to have these two depots of the same size. At these depots were to be stored all supplies for the departments of engineers, quartermaster, signals, etc., except ammunition. There was some delay in getting the work at Montierchaume started. In fact, it was not begun until March, 1918, so that it never reached the size of Gievres, but it would have done so had the war continued. Provision for the ammunition which was not handled at Gievres and Montierchaume, on account of the danger of explosion or fire, was made by constructing two yards to hold nothing but ammunition at Mehun, a few miles east of Gievres and on the same line of railway, and at Issoudun, similarly located with respect to Montierchaume.

The general principle on which the storage depots were laid out was to have the large base depots at St. Sulpice and Montoir serving the groups of ports on the Gironde and Loire Rivers, and the intermediate depots at Montierchaume and Gievres as the next advanced storage for these groups of ports respectively. But as other ports were turned over by the French or British for American use, other storage depots had to be constructed which, though individually small as compared with the huge installations already described, were nevertheless far from being insignificant. Especially was this the case since by far the greater part of this extensive and expensive construction was for temporary use only and had little prospect of future permanent value.

A small base depot was erected at Aigrefeuille, near La Pallice which, however, was not decided on until May, 1918, with an initial installment of twenty-three miles of track, a covered storage area of 204,000 square feet and an open storage of 430,000 square feet, the whole covering about 300 acres. Only a small proportion of this work was completed when the orders for cancellation came following the cessation of hostilities.

When it was decided that Marseille should be used as a port of embarkation, it became necessary to locate a storage depot at that point. A site was selected at Mirimas, at the junction of the two double-track lines of the Paris-Lyon-Mediterranée railway, thirty-three miles west from Marseille, there being no point nearer to Marseille than this on account of the rugged topography of the country. The plans for Mirimas contemplated 108 miles of track, 120 warehouses with a total of 2,500,000 square feet of covered space and 12,000,000 square feet of open storage, the whole yard covering more than 1,000 acres. Had the war continued and Mirimas been completed, it would obviously have ranked in size with the two large yards at Montoir and St. Sulpice, but only a small portion of the work had been finished when the war came to an end.

Similar preparations for a large storage yard near Brest had been located at Pleyber Christ, thirty-two miles away, nothing nearer being available for the same reasons which prevailed at Marseilles. This development, on which no work was started, contemplated thirty-two miles of track, thirty-six warehouses, 816,000 square feet of covered storage and 2,000,000 square feet of open storage area. A small storage yard had also been built at St. Luce near Nantes.

Large and capacious as was the forward storage area and regulating station at Is-sur-Tille, the engineers of the Transportation Corps recognized that it would not be ultimately sufficient.

A second site was chosen at Liffol-le-Grand, located in the department of the Vosges, with similar railway connections as at Is-sur-Tille, although it was some miles further to the east. Plans for Liffol-le-Grand had been prepared by the French. These were completely revised by the American engineers who drew new plans providing for seventy-two miles of track with 400,000 square feet of covered storage and 1,200,000 square feet of open storage. Work at Liffol-le-Grand was begun in April, 1918, and practically the whole of both the covered and open storage had been prepared in time for the American offensives of St. Mihiel and the Argonne. Both the yards at Is-sur-Tille and Liffol-le-Grand were connected with the large railway yards and storehouses at St. Dizier, a French regulating station, which became a base yard for American occupation and use during the Argonne attack. The total covered storage constructed by the A. E. F. in France and exclusive of more than 1,000 acres of open storage amounted to the following:

Depot Storage:		
Gievres	3,839,000 sq. ft.	
St. Sulpice	2,627,000 sq. ft.	
Montoir	3,447,000 sq. ft.	
Montierchaume ...	1,214,000 sq. ft.	
Is-sur-Tille	1,355,000 sq. ft.	
Other depots	3,047,000 sq. ft.	15,529,000 sq. ft.
Dock Storage		3,028,000 sq. ft.
Miscellaneous Storage		3,958,000 sq. ft.
Total		22,415,000 sq. ft.

From various types of construction, including even buildings with steel frames manufactured and sent from the United States, the type that was finally adopted as the standard, after some experimenting, which was quite suf-

ficent for practical purposes, provided for a building 300 feet long, fifty feet wide. The frame was composed of round posts four to a bent, the bents being about fifteen feet apart. The roof trusses were made of six by one inch boards, the roof and ends were covered with corrugated iron and the sides were left either open or were covered with canvas. These buildings were erected very quickly, in fact, there is a record of one having been put up complete by sixty-one men in eight and one-half hours. There was no wooden flooring except in buildings where supplies were kept that were readily vulnerable to injury by moisture, such as salt, sugar, and flour.

The greatest part of railway construction done by American forces in France was in connection with the various storage depots. As a general thing, the main lines of the French railways were capable of handling all the tonnage that was offered, especially after the intensive American methods of operation had been introduced. It was, however, necessary, in addition to building the storage yards, to increase the local facilities such as constructing additional side tracks and engine terminals, and to relieve points of congestion by new main tracks. Of the last, the most important was near Nevers. At this place there was a junction of east and west and north and south railways, fixing a moderate limit to the amount of freight that could be sent through. Inasmuch as the east and west line was to become one of the main lines of the American service, it was decided to build a new short double-track railway passing to the south of the city of Nevers, and avoiding the junction congestion. This was the most ambitious piece of railway construction undertaken, involving as it did, 162,000 yards of excavation, 428,000 yards of embankment, a large bridge and trestle 1,400 feet in length crossing the Loire River and Canal, and an overhead bridge crossing the Paris-Lyon-Mediterranée Railway. The whole project was

five and one-half miles in length, effecting a saving of 8.6 miles in operation and an elimination of junction delays.

There was considerable talk in American papers that the Amercan engineers were constructing a four-track railway across France. Fortunately, because the engineers had quite enough to do without undertaking unnecessary work, the only justification for this rumor was the doubling of an existing double-track line over a distance of about four miles just east of Bourges. At this place, there was a convergence of the tracks from Bordeaux and St. Nazaire. It would have been impossible to carry the tonnage over the one double-track line for the short distance to the place of divergence. This work of adding two more tracks to the existing two tracks was undertaken and completed by November, 1918.

Other main running tracks were built in connection with the various base and intermediate storage depots in order to give access to the existing French lines. Engine terminals solely for the use of American operation were built at Montoir, Saumur, Gievres, Cercy-la-Tour, Is-sur-Tille, Liffol-le-Grand and on the main line running out from Bordeaux at Perigeux and Montierchaume. All these engine terminals were finished and placed in operation.

The Transportation Department also undertook, in case the war should continue, a study of how the carrying capacity of the entire French railway system might be still further increased so far as it affected American plans. This study included the preparation of tonnage and density charts, an examination of possible routings, of desirable locations for new yards, regulating stations and other facilities. Studies were also made of the routes and possibilities of further development of the French canal system, and of railroad lines to be used and facilities to be required in the event of the possible

advance of the American army to the Rhine. The total length of the standard gauge lines including yard tracks constructed by American engineers in France amounted to about 1,000 miles.

The carrying out of these projects, involving as they did, modifications of the French railway system and of certain radical changes in their methods of operation, produced at times long and tedious negotiations.

The plans of each project, after having been designed and authorized by the proper authorities of the American army, were submitted to the French government. The French railways were under the general jurisdiction of the Minister of War, who acted through the Minister of Public Works and gave final approval on all such matters. The latter Minister was assisted in this work at first by a bureau designated as the Fourth Bureau of the Ministry of War, later by a board called the Franco-American Special Service. After the plans reached the hands of the Minister of Public Works they were submitted by him for approval to the French railway company directly concerned. Because of the wide difference in operating methods and inherited traditions, the plans were seldom accepted as designed and counter propositions were usually presented. To eliminate red tape and minimize delay, the Minister of Public Works finally directed the American Director General of Transportation to submit designs for new work to the particular railway company interested and, after having secured the approval of the officers of that company, to submit the design formally to the French government and the American General Staff. The approval of the French government, when secured, carried with it the right of acquisition of the necessary land and conveyed authority under which the work was to be undertaken. The approval also contained a clause as proposed by the American Director General of Transportation that " in

the event of any or all of these facilities being retained by the French government, railway or service after it has served the purpose of the American army credit should be given the American army for the work performed and materials furnished."

In many cases the French railways or the marine service deemed it necessary that additions to existing facilities or entirely new facilities should be constructed on account of the extra burden imposed on them by reason of the American traffic. In such cases, where the plans were prepared by the French, they were sent through the Minister of Public Works to the Director General of Transportation for acceptance.

Naturally, with ideas originating from so many sources, French as well as American, government officials and railway managers who had been trained along lines based on absolutely opposed hypotheses there developed what at first seemed to be irreconcilable difficulties. But, as is nearly always the case when men are imbued with a determination to find a working solution, the impossible was gradually resolved into the possible, differences were adjusted, difficulties were minimized, and official machinery made to run smoothly. Credit for this is largely due to the broad-minded force of Albert Claveille, Minister of Public Works. When hostilities ceased plans covering no fewer than 316 different projects had been approved. The total extent of French railway wholly or partly used by the American army exceeded 5,000 miles.

CHAPTER IX

AMERICAN LOCOMOTIVES AND CARS

Although many American methods of railway operation were introduced in France, it is very doubtful whether any one of them has secured a permanent resting place so as to be recognizable hereafter. There may be here and there a slight modification of French methods but it is hardly likely that there will remain any visible effect of American influence. French methods are well adapted to local conditions and to the national temperament, and probably will not undergo much change as a result of the war. French railway rolling stock on the other hand is much more likely to show hereafter modifications in its design. So many locomotives and freight cars of the standard American type and manufacture were sent to France, and have been left there for French use, that it seems impossible that the French design of their own similar rolling stock should escape from being considerably influenced. It is hardly conceivable that French railway officials, who are exceedingly intelligent and progressive, will return to the exclusive use of their old models when they have become acquainted with locomotives whose mechanical details are simpler than theirs, with larger freight cars, with cars on bogie trucks equipped with air brakes, and with the economical advantages presented thereby.

Of the nine original regiments, there was but one, the Nineteenth Engineers, that was recruited entirely from the mechanical crafts and intended for the sole purpose of repairing locomotives and cars. Although this regiment was formed, as the others were, on the basis of two

battalions of three companies each, it was later expanded to a regiment of fourteen companies, distributed among five battalions, and comprised about 3,600 men. On its arrival in France it was confronted with the situation as previously described, namely, a shortage of equipment and the existing equipment, such as it was, in bad repair.

It was intended that the new large shops of the P-L-M Railway at Nevers in course of construction when the war broke out in August, 1914, and never completed, should be used as the main place where American rolling stock should be repaired. But the great buildings were not entirely under roof, and the special heavy machine tools necessary for work on locomotives were not in existence in France. Consequently the six companies of the regiment were distributed between as many different and widely scattered places, while work on furnishing the structure of the Nevers shops and equipping them was ordered to be rushed.

The company of the Nineteenth Engineers located at St. Nazaire was engaged in erecting American locomotives as they were discharged from ship. The remainder of the regiment was assigned to overhauling French rolling stock, and the whole of the Thirty-fifth Engineers was detailed to the erection of cars as fast as they were unloaded from the ships. Practically all such car erecting was done by this latter regiment.

The companies assigned to work in the French railway shops were under the control of the French military authorities. As might have been expected, these men were greatly embarrassed at first by their lack of knowledge of the French language. The men were strangers to French equipment and tools, and especially to French methods of working, which to the average American mechanic were often incomprehensible. All this naturally engendered a lack of confidence in the Americans on the

part of the French, who for some time would not trust the Americans to proceed with their work without having a Frenchman constantly at their side to supervise their most simple tasks. This lack of confidence was not shared in the least by the higher officials of the railways who, without exception, were appreciative of and grateful for the assistance rendered. As time went on, the obvious benefit of allowing the Americans to work by themselves and follow their own methods became apparent to the French, who directed that thereafter the Americans should be organized into separate gangs in the various departments under their own leaders, a step that was followed immediately by a marked increase in efficiency.

During the latter part of 1917, it was clearly evident to all concerned that the French equipment had deteriorated to such an extent that unless large forces of men were assigned to repairing their locomotives and cars without delay, serious difficulty would be encountered in handling the railway traffic, with a resultant bad effect on the general situation. A hurry call, at the request of the French, for locomotive and car repair men was cabled to the United States. The answer was a total of 2,645 men who were distributed among fifteen different railway repair shops under French charge in all parts of France.

By the spring of 1918 the main shops at Nevers were nearly completed and the Nineteenth Engineers were so expanded in size as to man them and the other shops as well. On June 21st the first locomotive was taken in for repairs and by August the shops were in full operation. By this time even the enlarged regiment was insufficient to do all the work, and other units, chiefly the Forty-ninth and Fiftieth Engineers, were placed under the orders of the General Superintendent of Motive Power.

The locomotive shops at Nevers comprised the following buildings:

Erecting, machine and boiler shops	350 ft. x 350 ft.
Smith shop	330 ft. x 70 ft.
Wheel shop	300 ft. x 80 ft.
Paint shop	130 ft. x 75 ft.
Foundry (temporary construction)	50 ft. x 30 ft.
Storehouse	175 ft. x 30 ft.
Offices (three stories)	90 ft. x 35 ft.

In addition to the above, there were: a refectory, ninety feet by thirty-five feet (intended for use of French workmen but used by the American troops as a Y. M. C. A. hut and later as an Officers' Club); a hospital or first aid room, fifty feet by thirty-five feet (used by representatives of the French railways); one single and two double houses (used as Officers' quarters); apprentice school (used as a power plant); an electrical shop and several minor buildings.

The main building contained: two erecting bays, each equipped with two sixty-five-ton cranes and two ten-ton cranes; three machine shop bays, the center one being equipped with a fifteen-ton crane; and three boiler shop bays, the center one being equipped with two thirty-five-ton cranes.

The locomotive shops' enclosure covered approximately forty-five acres.

The main building had been designed originally as a steel-frame structure, but the shortage of steel during the war compelled the French to redesign it to be made of reinforced concrete. As such they completed it, and produced a magnificent building. The French furnished a special water service from the Loire River, whence water was pumped into a concrete tank holding 100,000 gallons. A complete and adequate sewer system was also installed.

According to the first French plans, power for operating the machine tools and cranes was to come from an electrical installation to be established at Garchizy, four and a half miles distant. The substation at the shops, where the current at 15,000 volts would be received, was to be equipped completely, including wiring, switchboards, distributing panels, etc., by the Americans. Unfortunately the Garchizy plant was not completed so that current could be furnished until 1919. The American engineers immediately on their arrival ordered boilers and generators to be sent from the United States, for a temporary steam plant. To furnish some power until the new apparatus should reach Nevers, they installed three 100 kw. direct connected generator sets and three 100 h. p. vertical boilers that were available in France.

The necessity for providing a shop for the general repairs of American freight car equipment was apparent from the start. The advantage of locating such a shop at Nevers was manifest, not only on account of having it supported by a thoroughly equipped machine shop and a general storehouse, but because Nevers was the most central point on the lines of communication for the A. E. F. Property for this purpose was available just opposite the locomotive shops, and while it did not lend itself to the most desirable layout, it answered the purpose sufficiently well.

As designed, this plant held 240 French or 140 American cars under repairs at one time. Storage room was also provided for 259 American or 500 French cars. These storage tracks were spaced so as to permit their being utilized, if necessary, in whole or in part, for tracks on which cars might stand while undergoing repairs.

A planing mill of sufficient capacity to handle the work of both the car and locomotive departments was installed at this plant, as was also a storehouse, a small machine

and smith shop, and four work buildings. The car shop enclosure covered approximately twenty acres.

This plant was finished September 6, 1918, and continued in operation until June 7, 1919, at which time it was turned over to the French.

It is exceedingly interesting to record that 5,764 French and American cars were repaired at the Nevers shops by American mechanics and returned to service.

The American standard gauge locomotives were almost wholly of one type. In all 1,610 were erected in France by American mechanics, of which 1,333 were erected for American service and 277 for French. Of these, thirty were small saddle-tank engines for work in yards, with 6,225 pounds tractive power; ten were 150 h. p. gasoline engines; and the balance, 1,570, were of the one pattern adopted as standard.

The last, which were used as road or train engines had a wheel arrangement described technically as 2-8-0, that is, one leading and four driving axles. Their main characteristics were:

Cylinders — simple	21 in. x 28 in.
Driving wheels — diameter	56 in.
Weight, working order	166,400 lbs.
Weight on leading truck	16,400 lbs.
Weight on driving wheels	150,000 lbs.
Tractive power	35,600 lbs.
Boiler pressure	190 lbs.
Wheel base, total	23 ft. 8 in.
Wheel base, driving wheels	15 ft. 6 in.
Tender capacity:	
Water	5,400 gallons
Fuel	9 tons

The locomotives were equipped with superheaters, air brakes and the regular French couplers.

American-made cars were used exclusively for freight purposes. 19,975 were received in France up to March

28, 1919, of which 18,441 of the following types had been erected:

Box cars	8,003
Flat cars	1,700
Gondola cars, high sides	2,858
Gondola cars, low sides	3,893
Tank cars	625
Refrigerator cars	950
Ballast cars	400
Dump cars	12
	18,441

Of the above, 17,866 were erected by the Thirty-fifth Engineers, principally at La Rochelle, the port of entry for such consignments, and the balance by the British at their shops at Audruicq (Pas de Calais).

These cars were designed in accordance with standard American practice except that they had the French type of couplers and buffers. The carrying capacity was 60,000 pounds. The box cars weighed when empty 32,640 pounds and the flat cars 26,500. The principal dimensions were:

Truck wheel base	5 ft. 6 in.
Center to center of trucks	26 ft. 2¾ in.
Length over end sills	36 ft. 2¾ in.
Length overall	39 ft. 10 in.
Width over side sills (boxes)	8 ft. $3^5/_{16}$ in.
Width over side sills (flats)	8 ft. 5¼ in.
Width overall (boxes)	9 ft. $6^9/_{16}$ in.
Width overall (flats)	9 ft. 3¾ in.

The extreme height from rail to the top of the French brakeman's hood on box cars was 13 feet 10¾ inches. All members of the underframes, and side frames of box

cars, were of steel, the flooring of all cars and the siding of the box cars were of yellow pine.

The work accomplished by American mechanics in the various repair shops was very great, amounting to:

American locomotives set up	1,333
French locomotives set up	277
American cars set up	17,866
American and French locomotives repaired (Nevers shop)	366
American and French cars repaired (Nevers shop)	5,764
French locomotives repaired (French shops)	1,474
French cars repaired (French shops)	52,850

The above figures cover erection and heavy repairs only and do not include light repairs to rolling stock executed in the small machine shops at Montoir, Gievres, Cercy-la-Tour, Is-sur-Tille, Bassens, Perigeux, Châteauroux and Liffol-le-Grand staffed by American engineers. The figures do not include the labor expended in erecting the machine tools and equipping the power plant for the Nevers shops, the setting up of sixty-seven steam shovels, pile drivers and locomotive cranes, the putting into commission of nineteen hospital trains received from the makers in England, and the shipping of more than 2,200 car loads of material prepared for other departments. They are also exclusive of the work of erecting and repairing the rolling stock for the light railway system which was done in the shops of that department with its own independent force of engineers, as will be later explained in Chapter XXI.

The supervising and controlling authority for all this work was vested in the General Superintendent of Motive Power, an officer under the General Manager, the latter being on the staff of the Director General of Transporta-

tion. The position was filled during the whole time by Colonel H. H. Maxfield, who went to France as second in command of the Nineteenth Engineers. In pre-war days, Colonel Maxfield held the position of Superintendent of Motive Power of the New Jersey Division of the Pennsylvania Railroad. In January, 1918, he succeeded to the command of the regiment and exercised the double function of regimental commander and General Superintendent of Motive Power. Under the latter authority he had jurisdiction over the work of three other regiments, the Thirty-fifth, Forty-ninth and Fiftieth, and some attached units. On the railway lines, the authority of the General Superintendent was transmitted through Superintendents of Motive Power, one of which was assigned to each of the nine Railway Grand Divisions.

CHAPTER X

THE CAMBRAI OFFENSIVE

The military situation when America entered the war was far from satisfactory.

On the western front the British and the French had, in the summer and autumn of 1916, conducted the campaign which is known as the battle of the Somme, during which the Germans had been driven back to a line running north and south through Peronne. There had been an Allied advance to an irregular depth varying up to seven or eight miles on a front of about twenty miles, a fine victory, but one purchased at terrific cost. In the latter part of the winter of 1916-1917 the enemy voluntarily made an exceedingly brilliant retreat in this whole sector between the river Scarpe, east of Arras, to the river Oise near La Fere, a distance of about fifty miles, to the carefully prepared position known as the Hindenburg line.

It was a clever move. The Germans gave up territory that was of no use to them, territory which as a matter of fact they retook, in a few days, in the great offensive beginning the 21st of March, 1918. In falling back they laid the country absolutely waste, every house was leveled, every railway and highway was destroyed. One of France's gardens had been changed into a desert wilderness. The Allies were thus forced to change their plans and to reconstruct from a military point of view the abandoned country before the advance could be resumed. In the meanwhile the Germans had securely entrenched themselves on ground of their own selection. On the eastern front Russia had collapsed, the Gallipoli campaign had been abandoned and the outlook in the Levant was dark.

In April, 1917, the French made an attack in force in the Champagne country, against the advice, it is said, of the military chiefs, an attack that gave but little result except losses whose totals have never been made public. Discontent was growing. There were socialist strikes in Paris with the red badge of anarchy openly displayed. The garrison forces of the capital were strengthened. In the north a series of isolated affairs was undertaken by the British whose chief value lay in strengthening the morale of the fighting forces and the gradual wasting of the enemy by attrition. Vimy Ridge was carried by Canadian troops and a satisfactory advance made by the British forces east and northeast of Arras. In June Messines Ridge was taken, leading to the third battle of Ypres. In July a wide attack was begun in Flanders but, as had happened with nearly every allied effort in that year, it was accompanied by heavy rains continuing for days which, in the level clay plains of the north, sufficed to bring that offensive or any other possible one to a standstill. Men and guns could not be moved in that sea of deep thick mud. During August and September the attack was resumed, resulting in the capture of the Passchendaele Ridge and much territory east of Ypres. But still no vital point had been reached, no serious break in the German lines was threatened.

By this time the first contingent of American Engineers was in France. The Eleventh, Twelfth, Thirteenth and Fourteenth Regiments had reached Aldershot in England, the first named arriving at the end of July. The Fifteenth and Sixteenth were on lines of communication in central France, the Seventeenth and Eighteenth had commenced the all important wharf construction at St. Nazaire and Bordeaux, while the Nineteenth was establishing itself to repair locomotives and cars.

The Eleventh Engineers were ordered during the

early days of August to join the British forces in Flanders to construct, they were told, some main lines of communication which were necessary to facilitate an advance in prospect. But after being held for a week near the Belgian frontier, countermanding orders were received and the regiment entrained for the Somme country, where it was soon joined by the Twelfth and Fourteenth regiments. The latter two were assigned to the very useful "light" railways which were the means of distributing ammunition and supplies beyond the points where standard gauge railways could not be maintained.

It was not long before it became evident that some great new movement was in contemplation. After a few minor engagements following the German retirement to the Hindenburg line in February, the Somme front, the scene of such bloody warfare during the preceding autumn, had become a "quiet (?)" sector, with only an occasional raid—"shows" the British Tommies called them — or an exchange of artillery compliments. The main activity was farther north.

Southeast of Arras, northeast of Peronne, and distant about eight miles from the British lines was Cambrai, a city of nearly 30,000 population in pre-war days and a highly important railway and road center. It had been uninterruptedly in German hands since its first capture by them in September, 1914. Its recapture in connection with the gains further north in Flanders would seriously complicate the German position and might easily involve, as the Somme battle had, a further retirement during the coming winter to a new Hindenburg line.

The battle which followed, General Pershing in his final report described as of "special interest, since it was here that American troops (Eleventh Engineers) first participated in active fighting."

To the American engineers was assigned the task of preparing the lines of railway communication to receive

the increased traffic that was soon to be thrown upon them, of constructing new lines of communication so as to be able to satisfy the voracious hunger of the new batteries about to be installed, of repairing abandoned main lines so that they might be reconstituted if an advance were secured, and what was a new experience, unloading and putting in position great fleets of tanks.

Much of this work lay in advance of the British guns, between them and the British trenches and at times in plain sight from the German lines. Under such conditions men worked only in small scattered parties to avoid notice, or in large forces at night and during foggy weather, times of "low visibility." New excavation was immediately covered with boughs or with camouflage so that it should not show in airplane photographs. Men thus engaged were under a cross-fire of shells both going out and coming in, and the Eleventh Engineers had the distinction of reporting the first American battle casualties as early as the 5th of September, 1917.

The tank was really the only entirely new creation of the war, all the other novelties in warfare having had a previous application or at least consideration.

The idea of the tank originated with a Frenchman, but was taken up and developed by the British Navy and put into use by the British Army. The Germans at first decried it, but after facing tanks for more than a year and a half, an experience that filled them with wholesome respect for this new development in warfare, they decided to use the innovation and actually put some on the field, though not in sufficient numbers nor in time to produce any material effect.

The British used them first in the Somme battle as auxiliary weapons with great effect. The original tank weighed about thirty tons, was armored heavily enough to deflect rifle bullets or shell splinters, and was armed with small guns. They were moved by caterpillar tractor

belts, one on each side, operated by a single engine and steered by a wheel rudder. Later they were given two independent engines of increased power, one driving each belt so that the tank could be steered without a separate rudder. One type of tank was armed with cannon posted in sponsons and called a " male," while the " female " had only a battery of Lewis machine guns. During the latter part of 1917 and the early part of 1918 the tank was subjected to close study by the three armies, French, British and American, with the result of bringing forth three designs. The first was a large machine similar to the early British tanks weighing thirty-five tons, armed as above and carrying a crew of twelve men. This machine had the advantage of weight and great battering force; it could cross trenches six feet wide with ease, demolish buildings and concrete " pill boxes " containing machine guns, and, with its heavy armament and large crew, possessed great offensive value. It had the disadvantage, inherent to its size, of being unwieldy and slow, its speed not exceeding two and a half or three miles per hour. The second type was a French model, a small machine weighing 15,000 pounds, carrying two men, armed with a 37 mm. (1½ in.) cannon or a machine gun and had a speed of five or six miles an hour. These little tanks, called " whippets," were largely used by the American army, especially in the Argonne operations. They were exceedingly efficacious against machine-gun nests, being in themselves proof against anything but artillery fire. The third type of tanks was one still smaller than the "whippets," weighing not over three tons, carrying like them two men, mounting but one machine gun, and having a speed of eight miles an hour.

In planning the battle of Cambrai, General Sir Julian Byng, commanding the Third Army, B. E. F., decided to use tanks on a much larger scale than they had ever

been employed before and in a new rôle. An attack in force had always been preceded by artillery preparation continuing for some time, perhaps for hours. The greatest number of guns that could be collected would be massed and, at a given moment, begin to scatter shells on the enemy front trenches and the wire entanglement in front of them, beating down the latter and making the former untenable. When this had been accomplished the range would be increased and the fire concentrated on the support or second line of trenches. Under the protection of this curtain of falling shells the infantry would advance and occupy the first enemy trench if all went well. Such artillery preparation was usually effective but it gave the enemy notice that an attack was coming and allowed him to take some provision for artillery reply, for resistance or for counter attack.

General Byng proposed to effect if possible a complete surprise, to use a very brief but intense artillery preparation and then to launch a great fleet of tanks which would trample flat the wire entanglements, drive the defenders from the front trenches and so permit an immediate infantry advance, the guns in the meanwhile giving tanks and men a forward protecting barrage, silencing the enemy's guns and preventing a counter attack.

Both the allied and enemy lines in this sector were lightly held, the greater part of both forces having been withdrawn to strengthen the offensive and stiffen the defensive operations in Flanders. It became necessary, therefore, for the British to return the old or concentrate new units on the Somme front, to move in the guns and to accumulate vast stores of ammunition. Extensive preparations were in progress during October and became intensified with the coming of November. As the success of the attack depended on its being a surprise, all movements had to be made under cover of darkness. For two

weeks prior to the battle the procession began to move as soon as it became dark. Railway trains showing no lights brought in their loads of men or artillery, who were at once detrained and moved to position.

The camp of the Eleventh Engineers was next to the main highway leading east from Peronne. All through each night during the period of preparation there could be heard the tramping of men, the grinding of wheels, the rumbling of guns and tractors and motor lorries, the last heavy with shells, as the column crawled eastward like a great serpent. We knew that there were other khaki-clad similar columns on other roads. But the movements of all were so nicely adjusted, that before each day broke a predetermined stage had been reached and visible activity stopped for twelve hours. Men were concealed during the day in ruined villages and the guns and wagons were parked off the road, leaving the latter quite bare and free. The enemy aviators could then come and inspect all they pleased if they were willing to risk air duels. They could take photographs to any extent but these would reveal no apparent change in the situation behind the lines. Perhaps there might be shown some shadows that suggested a concentration, but suspicion would be laid at rest by the photograph on a following day showing the same shadows. What the photographs did not tell was, that the shadows which appeared to be the same, were shadows of other guns and of other men.

After all the disappointments of the year the weather now and for the first time favored the Allies. For two weeks there was a dense fog every night completely blanketing the ground and making night flying absolutely impossible, so the Germans did not have even the chance that a night machine flying low might permit the observer to note the dark procession on the white roads.

At last we knew when the battle was to begin. An

attack was always laid out on a detailed schedule somewhat resembling a railway time table. The commencement of the affair, usually the artillery opening, was fixed at "zero" hour, and then each subsequent step, such as the change of range, the establishment of the barrage, the infantry going over the top, at so many hours or minutes reckoned from zero time. This schedule would be given to each unit commander, and then all that remained was to notify the several commanders at the latest moment what the equivalent of the zero hour would be expressed in local time. Each commander would then correct his watch with the standard time at headquarters and carry out his orders, beginning at the exact minute. On November 18th we were notified that zero hour was 6:30 A. M., substantially the beginning of day light, on November 20th.

The Twelfth Engineers had charge of certain light railway lines which they had put in order. The Eleventh Engineers had been ordered to be ready, as soon as a sufficient advance was effected, to relay the track on the main line of the Nord railway running north into Cambrai. The Germans had taken up this track at the time of their retirement in February, 1917, had carried away the rails, fastenings and crossties, and had blown up the bridges. The American engineers had in the previous weeks removed the debris of demolished bridges and filled shell craters so that the roadbed might be ready to receive the new track. That the Eleventh Engineers might be in readiness to act promptly, a part of the regiment was ordered to assemble immediately behind the attacking line. The commanding officer directed the author, at that time second in command, to remain the night of the 19th-20th at regimental headquarters should any change of programme requiring executive action arise at the last moment, but otherwise to join him in the early morning at the advanced post.

The morning came and with its coming there vanished the fog that for so many nights had been such a comforting cover. With the regimental surgeon and a battalion commander I left camp at dawn. The air was sweet and crisp as might be expected in late November. To one who was not a professional soldier but who had always taken a keen interest in military affairs, had read of battles, had as a small boy seen France once before under the heel of the German oppressor, but who had now reached a point in life when there was no reason even to dream of taking part in war, the sensation was peculiar. In spite of all seeming impossibility I was to see and even take a part in a great battle, to witness a blow struck and, to the extent of the power of one individual, to aid the force of that blow against the long-time enemy of France, and now the enemy of my own country.

From stories and accounts of other battles that I had read I had a mental picture of disorder along the highways leading to the field, of stragglers, of belated convoys, of wrecked vehicles lying by the roadside where they had been overturned to clear the way, of staff officers and orderlies galloping along to restore order out of disorder and to hasten onward some detail of men or consignment of material specially needed.

As we motored to the front there was no confusion along the road, in fact the latter was quite empty of any traffic except for three little one-horse carts, that had no connection with the day's work, and a large covey of fine partridges flushed by the noise of our motorcycles. There were no stragglers, no wrecks and no dashing horsemen. The processions of men and supplies that we had heard passing frontward for a fortnight had all reached their destinations. Every man, every gun, every shell was in its appointed place, a magnificent and perfect piece of staff work. Then precisely when the zero hour arrived, all along the British front for some twenty

miles or more there arose a simultaneous roar from every gun, a roar that was to continue unbroken, night and day, for five days. The battle was on! Then to the ear there came another sound, another roar, slightly more muffled with not quite the same sharp crack, the din of bursting shells as the German guns began their reply. But the great difference in volume between the two was clear evidence that there was a wide discrepancy in the number of guns employed on the two sides. The German guns were evidently outnumbered, the surprise was undoubtedly a success.

The Eleventh Engineers had been ordered to remain under cover in reserve until such time as it was certain that the enemy had fallen back and that no immediate counter attack was imminent. While waiting I went into Havrincourt Wood which was the center of the attack. There the British eighteen-pounder field pieces were standing almost wheel to wheel, with only enough space between them to permit the crews to serve the guns. Every gun was in action as fast as the gunners could shove home a shell and close the breech. Some infantry battalions were there, whose time for taking part had not yet come. They were passing the moments of waiting with foot races and other sports. There were no last letters being written, no farewell messages being sent. Beyond in some fields across from the ruins of what was once a fine sugar mill was a whole division of Bengal Lancers, some 12,000 or 15,000 splendid figures with khaki turbans surmounting their black-bearded swarthy faces, hoping that all the lines of trenches would be carried so that they could at last have the chance of galloping far afield among fleeing infantry.

There was little news. There was a rumor that the village of Havrincourt in our immediate front was quite cleared of the enemy. That was all. It suggested the account by Henry M. Stanley of his experiences as a Con-

federate private at the battle of Shiloh, how as he lay wounded on the field he had not the slightest knowledge of how fared the day. The nearer one gets to the front, the less one knows. He can see only those things that are in his immediate neighborhood. He has no breadth of vision, no perspective.

Then there came down the road, marching westward, a little procession of perhaps fifty figures in field-gray uniforms, the first prisoners, mute but satisfactory evidence that the enemy lines had been reached. Their faces, the first freshly captured prisoners I had seen, made a curious study. There was a mixture of all sorts of men, from quite young boys to men of thirty-five. Some were sullen, some just stupid looking, others rather interested in their new surroundings, while some were unmistakably nervous as to what might be in store, in striking contradiction to those who were evidently not displeased to realize that the war, at least in active fighting, was for them at an end.

Then came another procession — unfortunately not the last — evidence that, if the enemy lines had been reached, it had not been done without cost. Men with heads and arms simply bandaged by the field surgeons, the walking wounded as they were called, going back for better treatment, and the little motor ambulances with two tiers of badly wounded, their feet only showing at the open end of the car.

An infantry column came up at a brisk swing. They have been ordered in. The commanding officer fell out and running up to two British officers standing by the road asked, "How's the news?" "Quite good," was the reply. "Thanks," he said as he turned to rejoin his men. How delightfully British, and how thoroughly un-American! Three sentences, six words on a matter of life and death in a great battle. The answer conveying absolutely no information but leaving everyone satisfied!

At noon we were informed that all the British guns had been moved forward, confirming our belief that the roar from the Havrincourt Wood was less distinct, that the infantry had occupied all the first objectives and that we could commence our work. The commanding officer directed me to go forward to ascertain the position. By 2 P. M. I had crossed the famous Hindenburg line, where the British soldiers were eating with much relish the breakfast the Germans had left, for after seeing the tanks coming, the latter had fled precipitately. A mile beyond and on the far side of La Vacquerie farm, no longer a farm but only a name on the map, were the British guns standing in rows in the open without targets, as contact with the enemy at that point had been temporarily lost. Just there the roar of battle had almost ceased, only the sharp crack! crack! of machine guns on the right, and in front of Gonnelieu, being heard as some scattered German outposts still held on and gave a little trouble. Before us were the spires of Cambrai cathedral only two miles away, and there was a rumor, unfortunately not true, that the cavalry were already beyond the city.

Among the guns were the victorious tanks, great awkward ungainly affairs, looking for all the world like some old dinosauria or other fossil pachyderms which, after many ages, had suddenly come to life. There were no visible signs of guidance and yet there they were slowly moving about with a raucous, grinding, grating noise, climbing in and out of shell craters, or flopping over gaping trenches with a motion similar to the rolling and pitching of a bluff bowed vessel making heavy weather in a tumbling sea. Some 400 of these monsters, that is the number we were told, had taken part in the fight and great service they rendered. They had taken the enemy quite unawares and gave him no time for preparation. They leveled the wire defenses so flat as to make them look almost as if they had never existed, so that the

infantry had gone on unchecked. It was a great plan that General Byng conceived and it succeeded admirably. It is said that the tank commander when he went into action flew from his flag tank a set of signals reading, "England expects every tank to do its damndest."

Stretcher bearers were moving here and there, picking up those who could not walk and carrying them to waiting ambulances to be hurried to some field dressing station, and thence to a hospital for full treatment. To these bearers the color of the uniform, whether khaki or field-gray, made no difference. Some figures which were lying quite still the stretcher bearers passed by. In a few hours a kind chaplain will read for them the sweet words of the simple service of the Church of England and there will be a few more white crosses scattered among that forest of crosses that stretches in an irregular wide belt across northern France.

In my pocket I had put that morning a flask filled with whiskey. During the afternoon the contents went in small portions to badly wounded. Finally but one little drink remained. But it did not have to wait long. I soon met a poor fellow sitting against the broken stump of a tree waiting for an ambulance. Part of his face was gone, and his wound must have been as painful as it was ghastly.

"Would you like a little drink, my man?"

The remaining half of his face seemed to smile as he replied quietly, "Yes, sir, I would, thank you."

He took the cup with great care, drank but a portion, and handing it to a man beside him, who I noticed for the first time had but a trifling wound in the foot, said, "Here, matey, I will go halves with you."

This incident was not the only exhibition of the fine spirit displayed. Somehow all the horrors and sufferings of battle seem to awaken in men not a thirst for more blood, for more slaying, but the kindlier, gentler traits of human nature. War is not all bad!

CHAPTER XI

THE CAMBRAI DEFENSIVE

After five days of hard fighting the battle of Cambrai died down. Cambrai itself had not been taken, the Germans having rushed in heavy reinforcements, whose pressure compelled the advanced British line to be contracted slightly through the villages of Fontaine-Notre-Dame and Bourlon, while possession of the wood of the latter name was retained by the British, though for a few days only. An apparently safely secured advance of some five or six miles in depth had been made, heavy casualties inflicted and a goodly toll of prisoners counted.

As soldiers in the field we knew nothing of the plans of the higher command. We looked down on the towers and roofs of Cambrai, we formed ideas of our own as to its importance to the enemy, we longed for a change of scene, and to have the novelty and excitement of entering a large city that had been so long in German hands. Especially because the city was still fairly well intact as, naturally, it had been spared by both British and French artillery. We hoped, therefore, that the fine advance that had been made, with the comparatively easy breaking of the Hindenburg line would furnish a good jumping off place, as we called it, for a new attack, a further advance, and another victory.

While the infantry were settling themselves in their new trenches and the artillery maintaining a continuous duel with the German guns, the American engineers had plenty to do.

The Twelfth Regiment were extending the narrow-gauge railway lines across what had been No Man's Land to reach the new battery positions, and converting the

lightly built previous front lines of railways into substantially constructed back lines as they now became.

To the Eleventh Engineers was assigned the task of strengthening and improving the standard gauge railways in that section, and particularly the task of putting in good condition the main line of the Nord railway, that prior to the Cambrai offensive they had cleared of obstructions. Before November 20th this railway had been in front of the British guns, but now on account of the advance, it lay behind them, and was so situated as to be a line of great importance should there be a further advance, or even if only the gain in ground already made were securely held. On the afternoon of November 20th they began, in coöperation with the Fourth Battalion Canadian railway troops, to relay the permanent way on the old embankment of this line that they had repaired with painstaking care. The general direction of the railway was north and south and it, therefore, crossed the opposing fronts diagonally as their general bearing was here northwest to southeast. There was no track left on this line for about five miles behind the British trenches. The enemy had removed the rails and ties, and had blown up the bridges when they retired to the Hindenburg line earlier in the year. For the above distance the British had not restored the track because the line lay so close to the front as not to be available for use, it being in plain sight from the enemy trenches for nearly the whole way.

After passing the German front line the railway route turned to the east towards Cambrai and thence away from observation, so that the Germans had been able to retain the old track in use almost to their front trenches. It was the relaying of this track that the American and Canadian engineers undertook, the advance made on November 20th having left the railway, if rebuilt, in a reasonably safe location for operation.

The Germans in their retreat that day made no attempt

or did not have time to destroy the part of the railway that had been in their hands. In fact, they had not even blown up the bridge crossing the Canal de l'Escaut at Marcoing. Holes were found excavated in the masonry and filled with explosives needing but a detonating spark to create a serious and annoying breach. All important bridges in advanced positions which might be seized by a surprise attack were usually thus mined by engineers and kept ready for instant demolition. But no spark reached the charges that day to explode them and one cannot help asking, "Why?" Did the officer or man who was assigned to this duty join in such haste the retrograde movement that he had no desire to tarry in order that his orders to demolish the bridge might be carried out, or did he simply forget, or did, perhaps, some chance shell win for him a little cross with the inscription, "One unknown German soldier"? In any event the bridge was found intact, and presently the engineers laid new rails across it and connected them with the abandoned German rail-head. Thus, for a few days, direct-rail communication between Paris and Berlin, which had been interrupted on every line since September, 1914, was actually restored. It is obviously not to be understood that trains were or could be run, but that a continuous track existed from the British lines across the new No Man's Land to the German lines and beyond.

This reconstruction involved the laying of eight miles of track, requiring eight days of very strenuous labor, as the line was being repeatedly shelled. November 29th in that year was the American Thanksgiving day, and as the through track connection had been made on the day previous, after a final twenty-two hours of continuous work, the national holiday was observed as a much needed day of rest. This was permissible because the artillery duel had slowly softened and by November 29th

we began to understand that no further advance was contemplated for the moment, and that we were not to have the excitement of entering Cambrai. The daily routine was resumed as it existed before the battle began. Once more the situation answered the description by the stereotyped phrase in the official communiqué—"Nothing to report". Our belief that quietness was really restored was confirmed by a letter from the army commander himself to the British officer in charge of railways in the army area, containing the following extract, which he conveyed to the troops concerned:

"Now that the Third Army offensive has reached its limit, and the normal trench warfare has been resumed, I would like to take the opportunity of giving you a short appreciation of the services that you and other transportation officers have rendered."

At that time and as a result of the attack on Cambrai, the new British lines constituted an almost rectangular salient projecting into the enemy's line, facing northeast towards Cambrai, about nine miles long and six miles deep with two sharply defined re-entrant angles, one at Gouzeaucourt on the southeast and the other north of Boursies on the northwest.

On Friday morning, November 30th, after the day of rest, the Eleventh Engineers proceeded to Gouzeaucourt with orders to begin the reëstablishment of the railway yard at that point, as the transportation department had decided to place there a transfer rail-head. The existing layout of highroads made this location highly convenient. It was known that no British offensive movement was intended and it was believed that nothing was imminent that would call for defense. As the officers desired the men to be free from any unnecessary encumbrance, only tools were carried, orders having been given that all arms should be left in camp. As the train carrying the men ran over the newly made track, some heavy shelling

was heard to the eastward. A few shells were seen to burst on the top of the ridge running parallel with the track where the British batteries were posted, but this excited no special comment. Suddenly at 8 o'clock the firing increased in intensity and became concentrated into a barrage. As such it advanced over the ridge, down the slope and finally rested across the track close to where the men were working. Then some British troops were seen falling back through the open fields, and the engineers recognized that an attack in force was being pressed by the enemy.

The Germans had succeeded in repeating exactly what the British had accomplished ten days earlier, the effecting of a complete surprise. They had, unknown to the British, massed troops opposite Gouzeaucourt and Boursies, and after a very short but heavy artillery preparation had launched simultaneously two heavy infantry attacks on the reëntrant angles of the newly formed salient with the intent, if a sufficient advance could be made, either to force a general retirement from the salient or, perhaps, to cut off a large body of troops holding it. The attack directed on Boursies made but little impression and was useful only in drawing men away from other parts of the line. At Gouzeaucourt it was more successful. The Germans quickly recaptured their own positions that they had lost ten days before, forcing the British first back to and then out of the lines they themselves had occupied before their own attack. Then pressing on they swept over the British lines and went beyond them.

To the engineers, the situation as it affected them was painfully clear. They were unarmed and, therefore, unprepared for any offense. The senior officer present recognizing that his men were being uselessly sacrificed, very properly ordered a withdrawal. This was attempted

at first by train, but the barrage was so intense that the train had to be abandoned, the locomotive only being saved. The men consequently became somewhat scattered, though not disorganized. Some succeeded in making their way under the command of their officers through Gouzeaucourt, some sought refuge in dugouts from the downpour of high explosive and gas shells, while some were rallied with British and Canadian soldiers separated from their commands into an improvised unit and offered resistance. They seized any weapons at hand, although some fought effectively with their picks and shovels until overcome. It is related that one fellow was seen to lay low five of the enemy with only a shovel before he fell. This irregular body undoubtedly delayed the advance along the main Cambrai-Gouzeaucourt road until the troops in reserve could be posted to make an organized stand. Casualties were occurring fast, while of the men who were in the dugouts many were captured, although one party remained in safety in a shelter for forty hours, succeeding in returning to their camp during the darkness on the second night, by which time a British counter attack had forced back the attacking line beyond the village of Gouzeaucourt. During the first day of their voluntary imprisonment a German soldier appeared at the entrance and calling into the darkness, asked who was there. One of the men replied in German that they were wounded Germans, an answer that apparently satisfied the enquirer, because he went away and did not return.

While the attack was in progress German airplanes flew low, sweeping the ground with machine-gun bullets. They did not spare even ambulances loaded with wounded, whose character was plainly indicated by large red crosses painted on the sides and roofs, several Americans already wounded being hit again while being transported. The barrage composed of both high explosives

and gas shells was very severe, so much so in fact, that an investigation made a few days later when the railway line had been recaptured, showed that a direct hit on the track had been scored every thirty-three feet on the average.

Such was the first participation of American troops in Europe in a major engagement. The picturesqueness of men fighting successfully, hand to hand, armed only with their tools against rifles and bayonets, undoubtedly enhanced the effect and went a longer way than perhaps the incident justified, towards establishing American prestige. For up to that time the fighting quality of Americans was quite unknown to the other armies. Official recognition of what was done on this occasion is shown by the award of two Military Crosses and one Military Medal by the British, followed by three Distinguished Service Crosses by the Commander-in-Chief, A. E. F.

The battle of Gouzeaucourt, or the Cambrai Defensive as it was officially named, followed the same general course as the Cambrai Offensive that began on November 20th. At the end of the first day the British brought up reinforcements and counter attacked, regaining some of the lost ground. Then followed an intense artillery duel, during which both sides used gas in large quantities. By December 4th the intensity began to subside and the British, realizing that the salient they had previously established was in a vulnerable location, gradually withdrew from some of the advanced positions to give them a line that could be held more easily. The net result of the two battles, the offensive and defensive, left an extent of territory in the hands of the British of about one-half of what they had captured between November 20th-25th, and probably a credit balance in the matter of prisoners taken and casualties suffered.

With the cessation of activity of the Cambrai Defen-

sive the campaign of 1917 came to an end. The year had begun with the German retirement from Noyon, Nesle, Peronne, Bapaume and the country lying east of the field of what is known as the battle of the Somme, and later was filled with a series of attacks and counter attacks which, on the whole, had netted a gain for the allied cause. There had been periods of great anxiety which were now relieved by the entrance of America into the struggle. But still the end was not in sight and, perhaps, the double battle of Cambrai well illustrated the futility of attacking until a great preponderance of force had been secured. Ten days after the counter attack had subsided and both armies were once more dug in, hard freezing weather came on, and there was nothing to do but to wait until winter was over. The general feeling among the troops was that the next offensive would be undertaken by the Germans.

The Cambrai Defensive had been a severe disappointment but, though the allied troops had suffered much, they were not discouraged, knowing that help on a larger scale was not far distant and that if they could hold on for a little longer final victory was assured. As a small illustration of their spirit it is recalled that while the German counter attack was still raging with the result in the balance, there was heard the sound of bagpipes one evening at the hour when darkness was just coming on. Then down the road a battalion of Scotch Highlanders was seen returning to reserve, having been relieved after defending an important position for several days against repeated attacks and great odds. They were marching in regular formation in "column of fours," or of "squads" as the American manual describes it, with their band at the head. There was but a handful of them, the others were in hospitals or lying in silence where the guns were banging away. They were painfully tired looking, but they marched in cadence and in forma-

tion. The Americans gave them a handclap but not a cheer as they passed, because no man in the crowd dared to trust his voice to cheer, but the Scots paid no attention to it, their jaws were set tight and every face spoke quite clearly of their determination, of their realization that, although cut to pieces, they had held their post until relieved, and of their pride that the honor of Scotland had been kept. All the while the bagpipes were screeching out a wild weird Highland paean of victory and defiance. Perhaps, that extraordinary instrument is the only one that could have done justice to the moment and occasion. The unit might have been decimated but it had not been beaten.

CHAPTER XII

THE AMERICAN "R. E.'S"

In the British service it is the custom to abbreviate all names to their initial letters, and what corresponds in the British Army to the Corps of Engineers in the American Army, namely, the "Royal Engineers," is always referred to as the "R. E.'s" in the same way as the artillery arm is shortened to R. A.

Several of the original engineer regiments were assigned to the British forces for long periods, varying from nine to twelve months, so becoming in actuality for the time being an integral part of the British engineer force. Among their associates and from the standpoint of service, they were "R. E.'s," but to distinguish them from British engineers, they were spoken of as the "American R. E.'s," the amusing contradiction in terms between the American and the R. standing for Royalty never being noticed. But on the other hand the appellation, "American R. E.'s," did convey a real sense of the friendly relations that existed between the engineer units of the two armies. They were one and the same.

It was interesting to watch the association of two bodies of men, with their opposite points of view, their different customs, their little peculiarities and personal idiosyncrasies, with a feeling at first on the one side that the others had been a little slow in entering the war and had left the common burden to be carried too long by others, while on the opposite side there outcropped that perfectly ridiculous superstition engendered by silly school books

that England was still the foe of what had been once her colonies. But gradually as both sets of men came to know each other better, they began to understand that if there was any surface antagonism it was nothing more than the ordinary antagonism of two members of the same family, ready to argue with each other but at heart united. And so it was! After the first few days of strangeness there developed between the American and British soldiers a close, warm friendship with the highest mutual respect, esteem and admiration. The mere being thrown together for a few days, the going of an American unit to a camp in England on its way to France, or the chance association in a rest area during the short term of a leave would not and did not suffice to break down the barrier of reserve on the one part or the little feeling of suspicion on the other. What was needed was actual service side by side, bringing the American and the Britisher together under a united command and for a long enough time to permit the men of both peoples to get through and beyond the screen of nationalism.

The effect of time and joint service in producing this mutual good will and understanding is shown in the experience of one American regiment, an experience that was fairly typical of all. When this particular regiment learned on its arrival in England that it had been assigned to the British forces, to be in fact British soldiers and under British orders, the disappointment was openly expressed through all ranks from the commanding officer down. Officers and men, with scarcely an exception, would have preferred any assignment to that. Six months later when this same regiment was detached from the British Expeditionary Force and ordered to the American Expeditionary Force the regret at the change was as widespread and as sincere as the disappointment over the first assignment had been. After a short interval the fortune of war suddenly and unexpectedly

brought the regiment back again into service with the British, a return that was hailed with wild enthusiasm. Although the regiment was again withdrawn there was always a hope among both officers and men that, perhaps, the fates would once more be so kind as to send them back again to Flanders Fields. In this particular case there was nothing in the composition of the unit to give the men a pro-British bias, in fact just the contrary, because more than fifty-five per cent of the men were Roman Catholics and at least one-half of them either Irish or of Irish descent.

On its way home a part of the regiment was placed on a passenger steamer on which were others not in the service. One day the commanding officer was seated on deck talking with an eminent bishop of the Church, who inquired as to the relationship existing between the men and the British. On being told how cordial it had been, he expressed his pleasure, mixed, however, with a little surprise, because he said that contrary stories in other instances had come to his ears. On being pressed he admitted that he had never heard the opposite view expressed by anyone who had actually served with the British. To give corroborative testimony the colonel stopped the first two officers who happened to pass and asked them to state their opinions and then directed that the very first enlisted man met should be sent to him. In a few minutes a man came up, saluted and said, "Sergeant Mc——— reports, sir," giving a good old Irish name. The bishop did his own questioning and finally said, "Now, Sergeant, I am going to ask you two questions. First, when you speak of 'Tommy,' I presume you are referring to the Canadians or, perhaps, the Australians that you have met?" To which came the answer, "I suppose I include the Canadians and the Australians, sir, but it was not exactly them I had in mind. It was the Englishman."

"And now, my second question," said the bishop. "Why was it that the men would have been glad to have gone back to the British, at any time up to the close of hostilities?" "I do not know exactly the reason, Bishop," replied the sergeant, "but, perhaps, one thing was that while we *believed* that in a close spot our own men would stand fast, we *knew* that 'Tommy' would."

In giving this answer the sergeant had not the slightest intention of making any adverse criticism or reflection on his fellow-American soldiers. He had served more months in the British advanced zone than anywhere else, he had become thoroughly acquainted with the British soldier, had learned to know and understand him, to appreciate his steadfastness and other good qualities, and was expressing an opinion of him in his straightforward way, an opinion that was not intended to be comparative.

The British soldier, or "Tommy," a contraction of "Thomas Atkins," as he was always called, was a remarkable person. Brave, of course, but then most, if not all, men are brave when properly led, his striking individual characteristics were, first, an indomitable doggedness, impressing everyone with the fact, as Sergeant Mc——— put it, that he "would stand fast," a cheerfulness that never failed him, never deserted him in the most trying hour of defeat or when sore pressed, a simplicity that never lost its charm or balance even when flushed in the most glowing moment of victory, an ability to accept conditions when he knew they could not be bettered and, therefore, to refrain from complaining, and a constitutional appreciation of the value of discipline. If he had a fault it was his inability to recognize when he was beaten. In spite of all that the Germans could do, that was one lesson they could never teach the "Tommies." So much did all this affect the Americans that on one occasion when there was being given a joint

Anglo-American vaudeville performance, that an American quartette asked to be excused from acceding to a request from the British officers to sing, "Over There," on the ground that the words were boasting. The song was, however, sung and received with loud applause by the British, but the men never allowed their regimental band to play it afterward without protest, so much so that it was soon dropped from consideration.

Then for a while the British officer was not understood, due probably largely to the fact that his mode of living was quite unlike the accustomed mode of the majority of Americans. To begin with, his hours were so different, for, unless he was compelled to do otherwise, he breakfasted when the American officer had already been at work for some time, he stopped for "tea," a seemingly awful waste of precious moments, and he dined at the outrageously late hour of eight or eight-thirty. For the latter function he dressed, that is, he saw to it that his uniform was clean or at least freshly brushed, and put on "slacks" or long trousers instead of wearing his riding breeches and heavy boots. At dinner all military talk or "shop" was absolutely taboo. Instead, the conversation was what one would hear in a London club, on travel, books, art, good stories, but never about war. All this struck the average American at first as flippant and superficial, an impression accentuated and not removed by the Englishman's habitual reserve until acquaintance begins to ripen into friendship. What the American did not know in the early days was that long after he had gone to bed, his British host with whom he had dined so excellently and agreeably had returned to his office quarters on his guest's departure, to work until the morning hours on his military problems when all light conversation was as much forbidden as the contrary had been at dinner. It did not take the American long to appreciate the good features of the British habits of

life and to value the great importance of the ability to lay aside cares and worries and to give the mind a much needed rest through thoughts on lighter things, even if only for an hour. Tea at five o'clock soon became an institution at more than one American mess.

Both British officers and men insisted on having their pleasures and physical comforts to the very maximum possible, even at times and under conditions that were really serious, though never to the point of interference with military duties. The officers saw to it that every opportunity was afforded to the men for their recreation, in which they themselves frequently took part. In this way they succeeded in maintaining a spirit of cheerfulness and high morale.

To what extent the British could do this right up to the very line of the guns greatly impressed the American officers in the early days of B. E. F. service. On one occasion a British officer whose battalion was doing a tour of duty in the trenches notified an American friend that a " show " well worth seeing was being arranged, and that he would send the latter a friendly hint in time. In trench vernacular, " show " meant an affair short of a major engagement, anything from a raid to an attack in force on a limited front. A few days later there came an invitation to tea on a fixed afternoon. On the American officer's arrival at the British post he was told that the zero hour had been fixed for 7:30, as it was desired to attack after dark, and that dinner had been set for 8:30. All this was said quite as a matter of course, as no one at the front ever contemplated, let alone went so far as to suggest that such a thing as a chance shell might seriously interfere with any personal engagement.

Meanwhile, tea was served in one of the headquarters' dugouts, a battalion headquarters precisely similar in general layout to many other headquarters along the front. Advantage had been taken of a high railway

embankment, into which and of course on the side away from the enemy a series of chambers had been excavated, the earth being held up by ordinary mine timbering or by semicircular sections of very heavy corrugated iron plates. The dugouts were about ten feet in width and perhaps as long. One was used for the headquarters office and officers' mess, another was the kitchen, a third was the signals office whence led the telephone wires to brigade headquarters, while others were used for sleeping quarters with superimposed bunks as in a sleeping car.

Through the open door of the dugout there lay what had once been one of the gardens of France which now, since the wave of the Somme battle had rolled over it during the previous year, had been transformed into an absolute desert, empty of all life but the soldier occupants. There in the distance to the left was Epéhy, once a prosperous place, now with not a single house standing. There to the right the tumbled broken wreckage of the sugar mill of Heudicourt. In the foreground two battalions between whom existed a strong athletic rivalry were settling some old scores or creating new ones in an exciting game of football.

Was all this really war? Well might doubt arise to question it, and still more to question the fact that in a few minutes a serious attack was to be made in which lives were to be sacrificed. The ruined houses, the broken trees, spoke war, but one was so accustomed to that sight! The fields were green with a tangled crop of weeds and wild grass, which, interspersed with bright scarlet poppies or blue corn flowers, looked gay enough to make one forget that they ought rather to be covered now with ripening sugar beets or dotted with fat grazing cattle. But there are two details that suggested the imminence of danger. If the players in the game were wearing white breeches and club jerseys as might be

seen on any English common on a holiday, the spectators dressed in khaki carried each a gas mask, ready for emergency, and just beyond was a row of six-inch guns that had only the night before been moved into place. As darkness descended, and the distant scene slowly faded, the game was ended, and the artillerymen began to strip their guns and the great piles of vicious-looking shells of the covering camouflage that during the daylight had hidden them from airplane observation.

At 7:25 the artillery fire which had been during the afternoon customarily irregular and lazily desultory, ceased entirely, a silence so deep as to be almost audible and oppressive because all knew what it portended. The football game was forgotten now as watch in hand one listened to the seconds slowly ticking away. At precisely the half hour there was a single warning shot, and then with one mighty voice all the artillery on a three-mile front, those guns regularly on station and all those others moved in to reinforce them for the occasion, leaped into action. That night they hurled not the ordinary shells, but some filled with thermite, another cheerful contribution of the chemical engineer, a finely divided metallic combination which oxydizes so rapidly on exposure to the air as to become molten metal.

The shells were so timed as to burst on high and directly over the enemy trenches on which there fell the rain of white-hot particles of the burning compound, setting fire at once to anything inflammable. It was like a wonderful display of fireworks on a gigantic but terrible scale, with the great flashes of the exploding shells and the steady continuous shower of falling sparks, with gun upon gun, battery on battery maintaining the supply of bursts and fire as fast as active men could serve them. It was not many minutes before the timbers holding up the earth banks of the trenches, the board walks at the bottom, the doors of dugouts and anything else that could

catch fire was in flames. The rows of German trenches on the hillside opposite were clearly marked in the darkness by livid bands of fire.

But even such a scene must yield to the pressing demand of dinner, and after an hour's watching a return was made to the dugout, where an excellent six-course meal was served.

The mess dugout was of the semicircular, iron-lined variety. Down the center was a narrow table seating ten. The tables and benches were of home-made design and army manufacture. But there was a white table-cloth, the glazed-surface kind that could be wiped clean, a dinner service of china, candles stuck in empty bottles for lights, and above all a genuine whole-souled soldier's welcome. There was a victrola in the corner playing a medley of ragtime airs and grand concert selections, and as the shells from the battery of six-inch guns in the neighboring meadow went screaming overhead, there was a steady flow of good stories. The guns, however, were pointed directly towards the open dugout door so the full force of the concussion of each shot was felt most strongly in the confined space, which after a while so tired the patience of the host that he, turning to one of his junior officers, said, "I say, Jones, please go down and ask those artillerymen to hold up their bally noise for a while. Tell them some gentlemen are trying to have a quiet dinner!"

On the way back to camp it was difficult to separate the confused impressions of a football game, an extraordinary artillery display, a delightful dinner and a sharp attack all at once. But the experience was not unique, it was the kind of thing that had taken place and would be many times repeated along the British front. It was their way of keeping up their spirits and remaining cheerful.

Sports were not only encouraged by the officers, but

they themselves frequently took part with their men. At one time " Tommy " and his commander might be giving and receiving hard knocks on the ball-field without regard to rank, but immediately the game was ended the one insisted on and the other never failed to give, and to give cheerfully, the snappy military salute. The Americans soon realized that in playing together there was no attempt at patronizing on the one hand nor the slightest feeling of servility on the other in the subsequent salute. They saw that the British officer, in spite of an assumed indifference, cared for his men as the officers of no other army did; they saw in him one brave to recklessness, as he was accustomed to lead his men over the top armed with only a walking-stick until expressly forbidden to do so; they knew that he never ordered his men to do what he would not do himself. Those qualities naturally won the full respect and implicit confidence of the men, and established between officers and men a mutual respect that won the admiration of the observer. It was the soldierly qualities, the close coöperation of officers and men, their cheerfulness, their manliness that Sergeant Mc——— saw, and that made him want to go back to " Tommy ".

It is a pity that more American units could not have served with the British forces, but it is hoped that enough did so to lay the foundation of a fuller understanding and a better feeling among all branches of the English-speaking race. In such understanding and feeling there lies the best hope for a world peace.

CHAPTER XIII

RELATIONS WITH THE FRENCH

To develop and cement a close personal friendship, to enter into and become an integral part of the life of other men, to reach beyond differences in national character and national customs, there must be completely unfettered freedom of speech. If there be in this respect any barrier no matter how small, the real spirits of men never meet. On account of the difference in language, therefore, there was not and there could not have been the same close intimacy between American and French soldiers as between the former and the British. Then, perhaps, the fact that the first and last were both strangers in a foreign land made another bond between them.

But there were two traits of French character that impressed the American, filling him with surprise and admiration; first, the calm self-control not only of the French soldier but of the nation as a whole, and second, the conduct of the French women. The comic papers have always indicated the three nations by certain typical characteristics. The Frenchman was represented as a very excitable and excited person, gesticulating wildly and getting much wrought up over nothing, while the Britisher was shown as a rotund complacent John Bull, and the American as a lanky passive Uncle Sam, the last two both models of imperturbable calmness, each in his own peculiar manner. The comparison is neither just nor accurate. No matter where the French were met, nor under how great a crisis, they were always calm, never

excited, a control and calmness that the people of neither of the other nations could surpass.

When in the South African war the news of the victory at Mafeking was received in England the people went wild. Great boisterous, jostling crowds surged through the streets of London and the English language became enriched by the word "mafeking," signifying a noisy and somewhat unruly celebration. Compare that occurrence with what took place in Paris on the famous November 11th. While everyone had for some days previously believed that the end was near, nevertheless on November 10th it was reported in Paris that the actual conclusion of the armistice might be delayed for one or even two days. When an American officer learned at the American headquarters at 9:30 A. M. on the 11th that the armistice had actually been signed that morning at five, and was to go into effect at eleven, he hastened to the street expecting to find Paris already *en fête* celebrating the consummation of her victory over her heriditary foe. But the great Boulevards were as quiet and orderly as on other days. There was no shouting, no excitement, no newspaper extras, no demonstration, and yet in ninety minutes the greatest war of all history that had held France on the rack for more than four years would be at an end. Meeting a French naval officer he imparted the news. "I had not heard it," the Frenchman said, "but hope it is true. I will inquire at the Ministry of Marine whither I am going." It was not until 10:45 that the Bourse confirmed the news to the Paris banks.

Then, but not till then, did Paris begin to celebrate. Shops were closed, flags were displayed, and without any ordinance or concerted action a general holiday was proclaimed or rather went into effect. But the crowds that filled the streets were orderly and exceedingly quiet. Only the Americans were making a noise.

During July and August, 1918, a part of one of the original engineer regiments was occupied in constructing for the First Army, A. E. F., an ammunition dump southwesterly from Château-Thierry. In the early morning of July 15th, heavy firing was heard, but the nature of it could not be learned. That day the officer commanding the regiment lunched with some French officers at a neighboring aviation camp, and during the meal one of the latter very casually remarked, and in much the same tone as if it were of no great importance, that the enemy had crossed the Marne in the early hours of the morning. Commencing with their first great offensive that began on March 21st, the Germans had launched a series of major attacks towards Amiens, Montdidier, the Aisne, and the Marne, each of which had netted large gains, but certainly in the popular and to a large extent in the military mind, the Marne, the scene of the first victory, stood as the great barrier beyond which they could not pass. Now they had actually crossed it!

Were the French officers excited? Not in the least! They had received no details, but were quite confident that Foch had the situation well in hand. Just then two American officers who were passing, stopped, in the hope of getting something to eat. The contrast between them and the French was interesting. They were full of both news and excitement. An attack in force had been made and a crossing of the river on a wide front effected with the advance still continuing. They also said the highway to La Ferté, the American headquarters, had been shelled and cut. Immediately after luncheon the commanding engineer officer started in a motor for Army Headquarters. He found the road intact as the French officers said that he probably would, but he soon ran into the flotsam of battle. There were ambulances and all sorts of vehicles, both motor and horse drawn, hurriedly impressed into service, moving southward with their

loads of wounded which were being distributed among extemporized hospitals in all the villages, and the upward flow of guns and ammunition lorries, of trucks and busses filled with reserves, all being hurried northward.

As he sped on through Coulommiers, Aulonoy, Jouarre and other smaller places, the people were standing in scattered groups talking very quietly, and though their earnest faces showed unmistakably that they fully realized the alarming situation of the moment, they were not excited. They had seen the advanced line of foam of the first great German wave of August, 1914, trickle through these same streets, they knew of those other great waves of the immediately preceding months that, rolling over villages and cities by the score, had washed them away, and now this very day there was a new wave just set in motion, with its oncoming roaring crest less than fifteen miles distant. Were their homes, which had seen one tide actually lap their very door steps and recede, now to be swept away? For them it was a terribly anxious moment, their all was at stake but there was absolutely no excitement, no running hither and there, no noise. As each new ambulance came up, they stopped their talking and gave a hand to help carry the wounded, for temporary rest, into their houses until other accommodations farther to the rear could be provided, houses that might be in ruins before another day's sun should go down. Would an American crowd have been so calm, so completely self-possessed? Perhaps, but they could not have shown a finer spirit, they could not have surpassed the conduct of those French people as shown under the trying conditions of that July 15th. We know now, what they did not know then, that on that morning the line of furthest advance had been reached, and that in three days the great counter offensive would begin, the first since Cambrai, and that this offensive was to con-

tinue along the whole front until final victory was gained.

France has suffered in the war as no country, no people has ever been called on to suffer. In her defense the women have given more than 1,300,000 sons, husbands, fathers who will never return. They lie buried on that continuous field that stretches all the way from the Vosges Mountains to the North Sea. The women have submitted to that sacrifice without complaint, and bravely doing what they themselves could do, in maintaining the home, in working in the fields, factories and mines, looking to and hoping for that day when it would all end. This they did with unsurpassed bravery for more than four terrible years, and now it is their lot to live on without those who were or later would have been their mainstays in life. To the women of France all honor!

The physical damage that has been done to the country cannot be imagined. To realize the full awfulness of it, the destruction must have been seen when it was still fresh, because the gentle hand of time has already begun to sear the open wounds and to smooth the scars. Although the actual destruction will not grow smaller, its fearfulness is already beginning to be less garish, and in a few years will have lost much of its terrible aspect. So soon are we led to forget!

But take a map of France and draw on it a line beginning at the Belgian frontier and running through St. Omer, St. Pol, Amiens, Compiègne, Château-Thierry, Rheims, Suippes, Pierrefitte, Commercy, Toul and Nancy to the German Alsatian frontier, and you will have roughly delineated this western or southern line of battle destruction. West of the line there are places that have been damaged by air raids, and some seriously so, such as Abbeville, Paris, Châlons, and Bar-le-Duc, but they are isolated cases. Between the above-described line and the northern boundary of France, an area more than 280 miles long and with a mean width of about fifty miles,

there is not a city or a village but that has been almost completely destroyed. Places along the outer limits may have been damaged in part only, but all towns and cities in the interior of the war belt have, without exception, been rendered uninhabitable. In many, many instances not only has every house been knocked down, but so completely demolished that not even the lines of the foundations or the location of the streets can be distinguished.

This territory was one of the fairest and richest of all France. Now it is laid absolutely waste. The houses where the people lived and the mills where they worked no longer exist, the rich top soil that produced year upon year its abundant crop has been blown away over extensive areas by the exploding shells, trees have been cut down, and the fields furrowed deep by trenches or covered with acres of wire entanglements.

Elsewhere than along the western fringe of the devastated district the civil population had been almost entirely evacuated, except in the coal districts in the north, where such as could work were allowed to stay. There women and children remained, doing their share by helping the miners or tilling the fields and thus releas-where there was not a house that did not show some damage, where not a pane of window glass remained, and living to all outward appearances entirely oblivious of war and death. It was really most extraordinary how they managed to continue the accustomed details of their normal life. As an illustration there comes to mind a picture of a sweet morning of a Sunday in early June in a little village among the coal mining districts near Bethune, whence the German trenches were not more than two or three miles distant. Down the main street constituting as is usual in France the sole street of the village and along which were ranged the miners' houses, every one with its battle scars, there

passed a procession of young girls dressed in white going to their first communion, a procession exactly like those other processions in which their mothers and grandmothers for ever so many generations had taken their part. It mattered not to them that an occasional enemy shell shrieked overhead. Poor little things, their memories could not in some instances recall the days when there were not such sounds and, therefore, they took them quite casually and as a matter of course now. The young brothers of these girls, too young as yet to be accepted in the army, and their mothers were filling the places of their older brothers and fathers in the mines that France might have coal for her factories to turn out guns and shells. The little old parish church to which the procession went, may have an ugly gaping wound in its roof, its windows may be quite destitute of any glass, and only a shattered stump of its belfry may remain, but the old white-haired curé, too infirm to render service in the trenches, still ministers to his flock, and under what remains of the shadow of the cross the women and children cling to home and work for France. Those little ones in white seemed to personify the splendid spirit of France that enabled her to face losses, damage and suffering such as no nation had ever been called on to endure.

But these were the workers. They were young and theirs was the hope of victory and peace and with that consummation the reunited family and the restored home. In contrast there comes another picture, one that has been many times repeated, perhaps the saddest type of picture of the whole war. It was in a little village in the Somme country where everything was absolutely destroyed. An aged couple had somehow obtained one of those much-coveted passes to visit their old village located in the fighting zone. They were looking for what

had been their home, something dear to us all, but perhaps dearest to a Frenchman who is not accustomed to travel and is particularly strongly inclined to live in the place where his forefathers lived. The old people had found the site they were seeking, but their house was like every other house for miles, just a pile of blackened stones. The poor old woman was seated on the broken mass eating a piece of dark war bread. There were no tears, tears could not flow under such circumstances, but the expression of mute agony on that poor old soul's face, as her eyes looked in silence on her life's wreck, told in unmistakable terms the story of her grief, of the full realization of her all having been swept away, and the recognition that the years remaining to her were too few to give her any hope for a resurrection. She, too, had bled for France!

This tenacity of the French to their homes, even when the homes had ceased to exist as habitable houses and when they were actually under the fire of their own French guns, caused annoyance to the Germans, as Mr. Brand Whitlock, the American Minister, now Ambassador, to Belgium, recounts in his admirable book, "Belgium." The French peasants behind the German lines in northern France, "in their stubborn and pathetic attachment to the land, continued to till their soil," as Mr. Whitlock says, and when the Germans were criticized for not evacuating these people, they answered: "But they do not wish to be evacuated. Try yourself to make them leave."

In pursuance to this suggestion, and with the view of saving the French inhabitants from destruction by their own or British fire, some of the delegates of the American Commission on Belgian Relief in the north of France were detailed to question the peasants. "They offered them the chance of leaving, but they would not go; they preferred to stay in their homes as long as their positions

were at all tenable, and to face the unknown dangers there rather than to confront the unknown dangers of the mysterious world outside. Peasants ploughed while an occasional shell fell in the fields about them, and old peasant women, driven from their homes by bombardment, crawled back at night to seek some shelter in the ruins that still had some air of familiarity.''

The French soldiers undoubtedly entertained toward their American brothers-in-arms a sincere feeling of true comradeship, to which they gave expression on every occasion. The following treatment of one of the engineer regiments is an illustration of French sentiment, with its roots striking through mere superficial politeness down into that earnest good will that the French troops and French nation offered to their transatlantic allies.

The regiment in question found itself in central France engaged on some construction work during the early days of July, 1918. The officer commanding the local French troops called on the American colonel and requested his coöperation in a military review on the forthcoming great French national holiday, July 14th. When they came to arrange the details it was found that the American officer was the senior in point of rank. The French officer not only at once conceded priority, but insisted that the American troops should occupy the right of the line, the position of honor accorded to rank, and that for precisely the same reason, the American officer should take the salute on the march past. On such an occasion the French ceremonial requires that after the troops have been inspected and reviewed, they shall be again formed in line and that a salute be rendered to the flag, posted with the appropriate color guard in advance of the formation in line. Now it happened that the French unit had no colors, colors during the war not being much used, and the French officer proposed that the American flag be saluted instead. The American

officer protested that it was a French holiday, that, in according the posts of honor to his regiment and himself America had already received more than her share of attention on such an occasion, but the Frenchman would listen to no objection. "Il n'y a q'une armée, q'un drapeau," he exclaimed.

Then on July 14th in the quaint medieval square of the old city, in the presence of the people massed on the sidewalks or crowding every window, and of the city officials with their tricolored scarfs grouped on the courthouse steps, the command, "Honneur au drapeau!" was given and the men of the two nations brought their rifles to the position of salute, there floated upward toward the old round tower, which legend says was once the residence of Richard Coeur de Lion of England, the strains of the stirring, moving "Marseillaise" and of the well beloved "Star-Spangled Banner."

The French recognized that there were different nations but only one aim. They were always very polite in acknowledging their gratitude, as they expressed it, for America's assistance to France, but they knew quite well that America was fighting its own and not France's battle and they much preferred to be answered that America was struggling with and not for France. It was the community of purpose, the identity of ideal that they saw and desired to have expressed, or as the French officer put it, "One army, one flag!"

CHAPTER XIV

FORESTRY

A British officer defined lumber as a munition of war. On account of its many applications and uses, the enormous quantity needed, and the fact that no substitute for it could be found or manufactured, it seemed to be entitled to the dignity of the higher classification rather than be treated as merely one of tens of thousands of articles grouped under the head of supplies.

France, thanks to the wonderful system of reforestration which she had been enforcing for many years, had been and during the war was able to supply in great measure her own local needs. This was not true for Great Britain, who had depended largely on foreign countries, America, Australia and the Baltic districts. Lack of ocean tonnage that could be spared for timber shipments during the war greatly reduced the available supply from all these sources, and Great Britain turned to France for assistance. France on other occasions had responded to other calls and she did not fail her ally in this one.

French forests are much more extensive and contain more large sized trees than an American would expect to find in an old, densely populated country where the forests have been exploited for centuries, accustomed as he is to the spendthrift squandering and sickening waste of his own once magnificent timber wealth. In France forests are the property of either the state itself, of the various communes, of certain public institutions such as hospitals or universities, or of individuals. In times of peace all forest lands, however owned, came under the jurisdiction of the Service des Eaux et Forêts, a bureau of the

Department of Agriculture, which administered the state properties and controlled to some extent the others. Indiscriminate and wasteful cutting of trees was forbidden. No section of forest land could be laid waste. Instead only a certain proportion of trees might be removed at one time, leaving enough to protect the half-grown trees and the young growth. When trees were cut, others were set out to take their places. Thus by cutting over a part of any forest area each year and by working in slow rotation over the whole area, it has been possible to get a regular annual crop and still leave the forest intact. In short, a French lumberman draws from his investment its regular product of interest and never touches the principal.

The French official and the French lumberman are also keenly on the alert against fire, an enemy to be feared quite as much as waste. By a proper staff of watchmen, by the removal of all fallen limbs and dead pieces, by systematically laid out clearings to prevent the rapid spread of fire should one start, and above all, through a wholesome respect for and realization on the part of the entire population of the enormous value of the forests to the nation, France has been spared those frightful and so unnecessary holocausts that have so often swept American forests. In this matter we as a people have much to learn.

The consequence was that, when after it was recognized that the war was to be a long protracted affair and that an overseas supply of timber could not be obtained, France could and did undertake to care for her allies as well as for herself. The peace-time forestry organization continued to function during the war, but to adapt it to the new conditions, to provide for allied needs and to correlate private with government interests, so that all might work for the common cause under intelligent direction, there was established the Comité Franco-

Brittanique de Bois de Guerre, under the direction of the Inspecteur General des Services de Bois. This Committee furnished the necessary machinery for the procuring of timber from government or state lands and arranged that there should be no conflict in demands, no unnecessary competition with inflation of prices and that waste should be reduced to the minimum.

This committee saw only to the matter of supply of and payment for standing timber, each army attending to the felling and sawing of the trees allotted to it. The British government organized a special forestry service from among the Canadian troops, but this force, like so many of the special forces, was inadequate to the huge task. Therefore, when the Balfour Commission was discussing, in May, 1917, with the American government the details of American coöperation, Lieutentant-General Bridges, the military attaché to the commission, requested that a special regiment of woodmen be raised to be loaned to the British army to assist in getting out various lumber products.

When the American Engineer Commission arrived in France, the French government made it very clear that enormous quantities of lumber of all sizes for all purposes would be needed and that, while they preferred that such material should come from our own forests, they recognized the practical impossibility of transporting such a bulky commodity when all available ship tonnage would be needed to bring the men and those supplies that must come from America, such as could come from nowhere else. They further stated that French forests would be at America's service to a limited extent. But the government also made clear the point that all the forestry force and all the cutting and sawing machinery with means of transportation from the forests to the main railways must be furnished by the United States.

With the American entry into the European timber field it was evident that the demand for timber was to be greatly increased and that the arrangements which had heretofore contemplated only the demands by the French and British armies must be reorganized. The first step was to enlarge the Franco-British Committee into an Inter-Allied Committee along the same general lines but with increased membership, wider scope and greater power. The details of the careful and highly organized methods for the control of timber lands and timber products, so far as they affected the army, are admirably described in the historical report of the Chief Engineer, A. E. F.:

"When the advance guard of American Foresters arrived in Paris in June, 1917, they found the French Government and Army highly organized for supplying the French and British forces with timber. Each of the French Army Groups carried on its staff a Forestry Service attached to the 'Direction des Etapes.' Under the Forestry Service of the Army Groups were Chefs d'Arrondissement and under them in turn Chefs de Secteur. This elaborate organization, maintained by the French Genie (i. e., Corps of Engineers), requisitioned existing stocks of lumber or wood, bought or requisitioned forests or obtained cessions of timber from the State Forests of the region, operated saw-mills with German prisoners or French Genie troops, largely handled its own motor and railroad transportation and functioned as a whole as a very intensely organized and specialized section of the French Army supply service. In the Zone of the Rear, a large organization had been developed under the Ministre de l'Armament et des Fabrications de Guerre for obtaining the stocks of railroad ties, aviation lumber, artillery and vehicle lumber, and all other forest products needed to carry on the war. This organization centered in the Inspecteur General des

Services de Bois in Paris, who directed the activities of some twenty Centres des Bois, the latter embracing all parts of France outside of the Army Zone. Each Centre de Bois consisted of a group of French engineers or forestry officers, headed by a Directeur de Centre, who represented the French Government in obtaining military supplies of forest products in a given region. The Centres de Bois had authority by presidential decree to requisition up to seventy-five per cent of the output of any saw-mill at a standard scale of prices fixed by the Inspecteur General at Paris. They also purchased special products like railroad ties, piling and so forth, at prices fixed by the individual Centre. They purchased or requisitioned forests, installed mills which were operated largely by German prisoners, but to some extent by French Genie troops; and formed, in a word, an extension of the Wood Supply Service of the French Army Groups over the entire territory of France, although under the control of the French Ministry of Munitions. The line between the Army Zone and the Zone of the Rear was very sharply drawn, and the organizations on either side of it were totally distinct. Within the Army Zone, the French Army Groups obtained their timber supplies directly by their own services and had practically absolute control of all forest resources within the Zone. In the Zone of the Rear, on the other hand, the organization was a civilian one, although made up largely of militarized personnel, functioning through the French Ministry and disposing of its products in accordance with such budgets or allocations as might be determined upon by the Minister of Munitions and the Minister of War."

In accordance with the habitual French respect for trained advisory bodies, there was organized La Commission Forestière d'Expertises, independent of the Inter-Allied Committee, but necessarily associated with it,

whose duty it was to determine the amount of timber on any private tract allocated to military service, to appraise the value and negotiate the purchase. The Comité permanent de Bois de Guerre, consisting of the Inspector General, representatives of the Department of Agriculture, prominent French lumber manufacturers and members of the French Parliament, laid down the lines of a general policy to be pursued by the government in regard to military demands of the allies, including, of course, the French, for lumber. The Inter-Allied Commission for the purchase of lumber, with headquarters in London and Paris, correlated all purchases of the allied armies from neutral countries, particularly Scandinavia, Switzerland, Spain and Portugal. Then there were the permanent government organizations such as the Ecole de Chemins de Fer, controlling the existing stocks of railway ties in France, and the Service de Ponts et Chaussées, with jurisdiction over the use and repair of roads, the disposition of timber along public highways, and the use of streams for driving logs.

All this may have seemed too complicated and unnecessarily cumbersome to the average American, unaccustomed to referring affairs to trained specialists. In fact, sometimes younger officers, not understanding European procedure, criticized the application of the principle, but it was the French method of reaching a result, and any other method would have ended in chaos.

As to the details of procedure of acquiring forests and how successful the French plan was, it is again convenient to quote from the report of the Chief Engineer:

" The group of foresters and lumbermen who came to France in August and October, 1917, were employed very largely on reconnaissance to locate suitable tracts of timber," * * * and the " reconnaissance for timber was extended over practically all France south of the occupied departments and the departments forming a base

for the British Army. Officers attached to the Central Headquarters of the Section, and the personnel in the Office of the American Delegate on the Inter-Allied Committee scouted continuously for timber in new regions, including the Central Plateau, the French Alps and the Pyrenees.''

As each forest was examined, a report upon it with recommendations for or against acquisition was submitted to the Chief of the Forestry Section, through the District Commander in all regions covered by operating districts.

If the forest was deemed to be desirable for A. E. F. operations, the representative of the Section at Chaumont was instructed to acquire it if possible, if the forest was situated in the War Zone area, while the American Delegate on the Inter-Allied Wood Committee at Paris acquired it if it lay in the rear of the Army Zone. In the War Zone, the acquisition of the forest was requested from the Direction des Etapes of the proper French army group, through the French Mission at American General Headquarters. The French forestry officers on the Direction des Etapes decided if the forest could be allotted to the American Expeditionary Force, and if so, proceeded to acquire it through their own field organization which negotiated directly with the French Forestry Service in the case of state or communal timber, and with private owners in the case of private timber. The Direction des Etapes possessed ample powers for the requisition of forests, which were exercised more freely than in the Zone of the Rear. Acquisitions in the War Zone, in the main, proceeded rapidly, all details being arranged between the local officers of the Forestry Section and the Chefs du Secteur of the Direction des Etapes.

In the case of forests in the Zone of the Rear, the American Delegate had first to obtain the approval of

the cession or purchase in behalf of the A. E. F. from the Inter-Allied Wood Committee. In the case of state or communal timber the consent of the French Forestry Service had also to be obtained. The allocation of the forest to the A. E. F. might then be made or refused, after considering our needs for it in relation to those of the French and British Armies. The Canadian Forestry Corps had established operations in four of the regions logically tributary to the A. E. F., namely: The Vosges Mountains, the Jura Mountains, the northern part of the Loire River Valley, and the pineries south of Bordeaux. Competition between the A. E. F. and the British Directorate of Forestry for desirable tracts was often keen and the allocation of the forest to one army or the other, if indeed the French did not reserve it for themselves, had to be thrashed out in the Inter-Allied Wood Committee. Once a forest was allotted to the A. E. F., all further details were settled directly with the French Forestry Service in the case of state or communal holdings. In the case of private holdings, the Commission d'Expertises was requested to estimate and appraise the timber and, if possible, to effect its purchase. This procedure was extremely slow, largely on account of the limited personnel available to the Expert Commission, a situation which was met as far as possible by loaning to the Commission a considerable number of trained American foresters to assist in the field estimates. If the Expert Commission succeeded in effecting a purchase, and in view of the difficulties encountered, its work in the main was surprisingly successful due to the energy and ability of its chief, a contract with the owner was made by the Centre de Bois concerned. If the Expert Commission was unable to obtain the forest by friendly purchase it was necessary to request the Comité Permanent to approve its requisition.

But the careful, thrifty French would not permit their

forests to be despoiled. Timber might be cut, but not wasted. To obtain the supply for the current year it was shown that it was not necessary to kill the growing supplies of future years. To this end the following requirements were enforced, as set forth in the report of the Chief Engineer:

"The methods of cutting state and communal forests were fixed by the terms of the cessions as drafted by the Conservateur of the district concerned. In the case of private forests, cutting regulations were outlined in the 'Procès Verbaux' prepared by the Expert Commission in the course of its appraisal of the timber. These were later embodied and sometimes changed in the formal contracts made with private owners by the Centres de Bois. The contracts were uniformly delayed until long after cutting had begun. In each district, however, a special liaison officer representing the Inspecteur General directed the methods to be followed in cutting private forests and settled complaints from owners. In the Army Zone, these duties were discharged by the Chefs du Secteur. In the state and communal forests, methods of cutting were closely controlled by the field officers of the French Forestry Service."

"The requirements of the French bureau of forestry were enforced in state and communal cessions. They were departed from in the case of many private forests which had been requisitioned or whose owners were favorable to a heavier cut than forestry rules would normally permit. In the southern pineries, following the forestry system of the region, the timber was cut clean and the requirements were comparatively simple. In a few instances the terms of the cession required the removal of the undergrowth of briars. In the hardwood forests and the softwood forests of the eastern mountains only trees selected and marked by the French foresters could be cut, and these usually consisted of

from fifteen to forty per cent of the total volume of merchantable material. In a few large hardwood areas, special concessions permitted the removal of as much as eighty per cent of the timber in the coupes cut over. The piling of brush was required in the pine and fir forests of central and eastern France, but not as a rule in the hardwood forests where the close utilization of fuel wood left nothing but small twigs. In a few instances, the pulling of stumps after cutting was enforced."

"The most serious restriction from the standpoint of effective logging operations was the limitation of the total quantity of timber which could be removed from many forests. In the state and communal forests of eastern France, containing many magnificent areas of fir and spruce timber, cutting was restricted to a limited number of 'coupes' which were ready for fellings under the exact methods of management applied by the French Forestry Service. Certain coupes of mature timber would be withheld, for example, because the regeneration of young trees was not sufficiently advanced. The markings in these forests, as a result of continued pressure by the American representatives who dealt with the French Forestry Service, were extended to include in some cases from five to ten 'annual possibilities,' that is, from five to ten times the quantity permitted to be cut in one year under the working plan prescribed for the management of the forest in question, all timber marked, however, being restricted to such as could safely be removed from the standpoint of maturity and the regeneration of the new crops. As a matter of fact, French forestry practice in this region is so conservative that several of these forests carried an excessive amount of old timber, and cuttings of this character and extent were not injurious from a purely technical standpoint. The most extreme illustrations of the application of French forestry requirements occurred in a few cases of large,

rich forests where the cutting of only a small fraction of the merchantable timber was allowed, this being restricted to wind-falls or thinnings."

It is hoped that the above lessons how to care for forests and to conduct operations have been learned and will be appreciated by our own lumberman.

The first unit of the American forestry force was the 10th Regiment of Engineers organized among the lumber districts of the west. It arrived in France on October 2, 1917, and was followed in quick succession by the 20th, 41st, 42d, and 43d Engineers, and the 503d, 507th, 517th, 519th, 523d, 531st and 633d Service Battalions. On October 18th, a forestry service was organized by combining the above regiments into one regiment known as the 20th Engineers, and the service battalions into attached Forestry Service Companies.

The regiment finally consisted of fourteen battalions of forty-nine companies and at the close of hostilities contained about 20,000 officers and men, the largest regiment in the American Army. Plans were under contemplation to increase the personnel to 50,000 men, which would have made it the largest regiment in any army of the world, larger even than the Fifth Engineers of the French Army, the famous unit of railway troops. It was commanded by Colonel J. A. Woodruff, who, with four lieutenant-colonels through headquarters at Tours, administered not a regiment, except in name, but a great manufacturing establishment. As indicating how actual figures exceeded the estimated requirements, the maximum forestry force likely to be needed was computed at the beginning of operations to consist of ten battalions of forestry troops, formed by three battalions of engineers and seven service battalions, a total maximum force of 15,000 men.

Much of the timber that was cut came from extensive forests without interior means of transportation. Nar-

row-gauge railways were constructed in those places where haul by motor, by tractor or by team was too great for reasonable economy. The main items of plant used by the Twentieth Engineers included:

282 sawmills,
1,850 logging wagons,
12,500 horses,
128 power tractors,
2,300 motor trucks and trailers,
400 miles of railway track of 60 c. m., 3 ft. meter and standard gauge,
2,070 railway logging cars,
85 locomotives.

The chief areas from which timber was cut were the Landes district south of Bordeaux, producing pine of a rather inferior grade, the Vosges and Jura Mountains, where firs were found giving splendid piles as long as 100 feet, and many scattered isolated forests through central France furnishing oak, beech and other hardwoods. The following table shows the total production by the American Forestry Section:

TOTAL CUT OF FORESTRY SECTION, DEC. 1, 1917 TO APRIL 1, 1919

	By Units Working for American Army	By Units Working for French Army	By Units Working for British Army
Lumber ft. B. M.	212,528,000	3,011,795	953,874
Standard gauge R. R. ties, pieces	5,065,000	210,124	219,366
Light railway ties, pieces	4,853,000	228,130	64,025
Total	222,446,050	3,450,049	1,237,265
Miscellaneous round products, pieces	1,883,504	39,095	1,194,817
Piling pieces	127,598	....	64,049
Fuelwood stores	14,102	....	12,295
Total	2,025,204	39,095	1,271,161

The lumber was used for all sorts of purposes, but the greater part for wharves, buildings, bridges and timber roads, although items such as packing boxes consumed much. The "Miscellaneous Round Pieces" include poles for telegraph and telephone lines, props for mines, dugouts and trench supports, and something like 1,000,000 stakes from two to five feet long, for wire entanglements. The maximum cut in one month (October, 1918) was 53,000,000 feet B. M.

At first the French authorities, in order to permit American engineers to commence work on the erection of the wharves and storehouses, undertook to supply the necessary timber by their own forces, with the understanding that American foresters would later cut for them at least an equivalent amount.

The prospect of supplying three large armies with construction timber over and above French commercial needs, all of which was to be cut from their own carefully preserved forests, naturally filled the French authorities with alarm lest the standing supply should be depleted seriously. Had the war continued this fear would have had reasonable justification, but even the great cut made by the American engineers did not amount to more than fifteen per cent of the normal annual cut in France prior to the war.

Although the men of the Twentieth Engineers were intended primarily to operate far removed from the battle line, and were given only a small amount of military drill and armed only so far as to furnish guards, nevertheless some of the work was carried out under fire, and more than one gold star stands to their credit.

One of the battalions went overseas on the *Tuscania* early in 1918. On the afternoon of February 5th the voyage was rightly considered over. The north coast of Ireland was in plain sight, only ten miles away on the starboard beam, when suddenly the ship was lifted by

the explosion of a torpedo. The few vessels that were near took off as many men as they could, but as some of the *Tuscania's* boats could not be lowered, owing to the listing of the ship, and others had been smashed, about 700 men were left on board with no help in sight. As the ship slowly settled they cheerfully sang:

> "Where do we go from here, boys,
> Where do we go from here?"

Then a destroyer came up and continued the rescue, but as it was, ninety-two found a resting place in Irish soil or with those many other men, women and children, who were victims of the silly, cruel policy that availed Germany so little and contributed so much to her eventual downfall.

CHAPTER XV

WATER SUPPLY

That an army cannot exist without water is axiomatic, but that in no previous war did an army need so much water as in this one is also true. The armies were larger, and besides the men and animals to be supplied with drink there were also locomotives and motors. In addition to quantity of water, quality was now considered for the first time, because general staffs realized that there was a difference in waters, and that, if the health of armies were to be conserved, only water of certain purity, or chemically brought to that standard, must be supplied.

To furnish the requisite amount of pure water for a city of say 50,000 population is no small task, but what of the task of furnishing enough water for that number of men who have been moved into an uninhabited area on a few days' notice? That was usually the problem given to the engineer. To solve it properly he must be something of a hydraulic expert, a chemist, and a bacteriologist.

The American army on arrival found water supply services established in both the French and British armies, and as the American forces were to occupy at first a small part of the existing front and gradually, as more troops arrived, a greater and still greater part, it was only immediately necessary to take over the installations already made.

Usually an army depended for its supply of water on a series of water stations, wells, streams, or reservoirs located substantially parallel with the front line and distant from it three to six miles, depending on the topog-

raphy of the ground and available source of supply. Water stations make excellent targets. From the water carts that are always standing by taking load the stations are easily recognized in aerial photographs, and on account of their importance soon receive attention from the enemy guns. They must, therefore, be kept out of range of the field artillery. These advance stations were very simple installations consisting of a gasoline operated pump, as a steam pump with its smoke would never do, a tank with a pipe line from the pump, stand pipe or hose from the tank to fill the carts, water-troughs and perhaps one or more pipe lines for distribution.

The difference in extensiveness between the French and British installations was quite marked. The theory of the former was that immobility of an army could not be, or at least should not be, believed to be of long continuance, and that, therefore, extensive water developments were but a waste of time and effort. Even though the front might be stabilized for long periods of time, as was the case, nevertheless the extent of the forces holding any given sector fluctuated between perhaps wide limits, approaching a condition of mobility. They argued that it was better to use local resources or, if they were insufficient, to set up other water points in great numbers, of small individual capacity and of the simplest character.

The British practice was rather the converse. They were inclined to dig or bore large wells giving a generous capacity of flow, which lead to a smaller number of water points for a given output. But the British installations being larger than the more numerous French ones, had a more complex equipment.

Good arguments can be advanced for either point of view. On the one hand that it is better to avoid concentration, when the failure of a single unit might have serious consequences; on the other, that the more permanent and

larger plant was less likely to go wrong through failure of mechanism, while the danger of concentration was more than offset by the safety arising from the inspection and control naturally attendant to a large installation. But the real reason for the difference arose from the opposing traits of national character. The same was visible in trench construction, in railways, in buildings, in fact in almost every detail of organization and execution. One nation by nature leans to lightness, delicacy and mobility, the other to strength, solidity and permanence. It made an exceedingly interesting study in psychology to observe the constant exhibition of the contradictory national tendencies. It is impossible to say which was the better system. Probably each army was right, because by following what was for it, the seemingly proper path the best results were obtained.

Some skill was frequently displayed in hiding water points, using ruined buildings for sites for tanks or putting pumps under an earth cover.

Pipe lines to the front were usually impossible on account of being exposed to breakage by shell fire, against which burying in trenches provided no shelter, as shells were effective far beyond any limit of practical depth of pipe trench. If pipe lines leading to the front in advanced areas were used, experience showed that it was safer to run them across country rather than along roads, as the latter were so frequently used as targets by the enemy when troops were known to be passing or in the hope of catching them by chance. As an uninterrupted supply of water was necessary, the lines had to be immediately repaired, if they were cut. To this end special gangs lived in nearby dugouts where they kept in stock a full assortment of tools and an extra supply of pipes and connections. The usual method of transportation and distribution to troops in advance of water points was by water-tank cars on the light rail-

ways, by automobile water trucks and horse drawn tank wagons. For storage in the trenches, nothing better was found than the ordinary gasoline cans or " petrol tins " as the British called them. They were light, non-breakable, of convenient size, easy to handle and good for no other purpose. For a while the water might have a distinct flavor, but under trench conditions, men soon learned not to be too particular in such little matters.

Such were the normal conditions of supplying water to an army that was stationary. So long as it remained so, the only concerns were maintenance, assurance that there was a proper standard of purity and the details of traffic control at points where perhaps sixty water carts an hour would report for filling. These are all matters of routine organization. It is when an army starts forward in a successful offensive with attending rapid advance, or worse still, a succession of advances, that real troubles begin.

The first thing to be done after it was seen that an attack was successful or that a foothold had been gained in the enemy's trenches, was to get without a moment's delay a supply of water to the newly captured position. It was there that the petrol tins rendered their maximum service. Across a shell-torn, wire-encumbered no man's land there were no roads, not even a horse cart could make progress, but eight two-gallon cans in two crates could be strapped to a pack animal and delivered to the men in their new position, where the small units, weighing about twenty-five pounds each, were readily distributed by hand. By such means, water actually reached men in their new objectives within half an hour after they had taken them, and there is one case reported where carrying parties delivered water to a new position in four minutes after its occupation. Water must be brought forward at once during the fighting, there should be no waiting. Having attended to the immediate press-

ing demand that will brook no delay, the next step was to organize a new source of supply, unless the advance was so small or so unimportant in extent as to permit water for the new position to be drawn from the previous points. First, the existing wells were found and, as little reliance could be placed on either streams or wells that were uncovered by an advance as not being polluted either by natural causes or by the deliberate action of the enemy, it was better to keep them posted as unfit for drinking until after they had been examined. This was the French rule and it was a very wise one.

The sources of supply which, after examination, were accepted were equipped with mechanical apparatus. Afterward additional sources, if needed, were dug or driven, the latter being preferred as giving quicker results and usually better water, as such wells furnished a supply free from surface contamination. Then pipe lines were laid, routes for water carts marked out and a new system established on a line more advanced than the old. As an illustration of what can be accomplished, the record made by the British engineers in carrying water forward after the battle of Messines Ridge, which began on June 7, 1917, is worthy of notice. On that date the troops at the front were supplied with water that came from lakes and catch pits well in the rear. By June 15th the pipe lines had been laid across the captured and completely devastated country and were delivering water into what had been German positions at a rate of 600,000 gallons daily. Under the conditions existing during the progress of a hard-fought battle, it was found possible to lay a mile of four-inch main in twenty-four hours.

So transcendently great is this matter of water supply that in the forward area it was found desirable in both the French and British experience, to have the establishment and control of water points and regula-

tions for distribution fixed by and under the control of the chief engineer of each army through a special water supply officer. In this way the questions of sufficiency, purity and distribution of water were coördinated for each army as an operating unit and not left to diverse and perhaps conflicting efforts on the part of subsidiary units such as divisions or even corps.

The French, in order to coördinate the service of their armies and to see that no one army received an unnecessarily larger part of the meagre supplies at the expense of the others, stationed an officer with the title of Chief of Water Supply at General Headquarters. He had broad authority over all water-supply work throughout all the French armies. For each individual army there was a water-supply officer reporting to the Chief Engineer of the Army. While carrying out the plans as laid down by the latter, he was assisted by the advice of the Chief of Water Supply and made requisitions on the last for any special equipment or additional amount of ordinary equipment that might be needed. Junior to the Army Water Supply Officer was a staff of assistant water-supply officers, each with an area under his jurisdiction which, while it might conform — as it usually did — with that of a corps or possibly of a division, this coincidence did not diminish the responsibilty of the assistant to his chief nor carry authority to the commanding officer of the smaller unit. Water supply was wholly an army function. Each assistant water-supply officer had a small force of skilled mechanics reënforced from time to time as occasion demanded by drafts from infantry or service battalions, the regular water-supply troops providing the necessary technical skill.

The British system was not so scientifically balanced. There was no general chief of water supply, each Chief Engineer of Army having absolute and final authority within territorial limits of his army. The component

corps commanders acting through the corps engineers had control of water problems that were peculiar to their own corps, and in this respect there was lacking the unity that existed in the French system. With the British there were no water-supply troops. Whatever work was to be done was executed by army or corps engineer troops except when mechanical details were concerned. These were taken care of by the Electrical and Mechanical Company, a unit quite similar to the American regiment of the same designation described in Chapter XVII.

The American Expeditionary Force, as it was being built up, made a study of both the French and British systems of organization and the details of their execution in the field. As in other matters, although the experience of the two Allies was most valuable and both countries extended every help and gave freely of advice, the American situation was not exactly like that of either of the other two and, therefore, for the A. E. F. somewhat different standards had to be adopted. The British front was not far removed from its base so that army influence predominated, using the word army in its technical sense of a certain definite combatant unit, French army needs for water supply were the only ones with which the French military authorities needed to concern themselves, because behind the Zone of the Advance the separate cities, villages or communes provided for their own wants or such additional demands that the war threw upon them.

But the A. E. F. had not only to supply the needs of its combatant force but also those of the great ports, storage depots, hospitals, semi-permanent replacement camps and intermediate headquarters that either did not exist with the French and British or, if they did, existed on a much smaller scale. An American water-supply organization, therefore, covered two distinct services,

first that of the Service of Supplies and second that of the Armies in the field.

Since the first detachment of combatant troops moved into certain portions of established positions in connection with the French where the water points were already in operation, it was not necessary to take any steps in regard to the second of the above services until there was a sufficient concentration of American troops at the front, which did not begin until late in the spring of 1918, beyond making plans and provision in advance. For the wharves at Bordeaux and St. Nazaire, for the operation and fire protection of the warehouses, for the camps being erected to hold the troops that were to come and for other similar water-consuming installations it was necessary to act at once to furnish water from either previously existing French sources of supply, such as neighboring municipal plants or from other sources newly developed. The Twenty-sixth Engineers, afterwards designated as the Water Supply Regiment, began to arrive in France in November, 1917, and undertook this work.

On August 7 and 8, 1918, there were issued from General Headquarters, A. E. F., a General Order and a Bulletin, Nos. 131 and 55 respectively, defining the organization of the Water Supply Service and giving official recognition to a system that had been in operation for some weeks. The G. O. and the Bulletin stated that the Water Supply Service was a branch of the Engineer Department, but that in the Zone of the Armies it would be administered through special troops assigned to the Army, the commanding officer of whom would be Water Supply Officer of the Army. It was the duty of the Water Supply Officer "to anticipate and make suitable provision to meet the water supply needs of the army and exercise such technical supervision and control over water-supply

work in the entire area occupied by the army as may be necessary to coördinate water-supply developments and economize time, labor and material.'' He was also charged with the making of laboratory and sanitary inspection necessary to determine potability and to prevent contamination. The laboratory facilities were provided generally as sections of the Medical Department.

Water supply for the Service of Supplies was an adjunct of the Director of Construction and Forestry, and was, therefore, distinct from water supply in the advanced area. Although there was lacking the unity of control as presented by the French organization, this was overcome by the various officers working harmoniously together in the matter of available supplies. Had the war continued it is likely that some system analogous to the French would have been adopted, the advantages of which were apparent, and the department concentrated under a single engineer officer at General Headquarters.

The great achievement in the matter of water supply, and it was a real achievement, was in the quality of water delivered. In all previous wars, typhoid fever has been accepted as a necessarily existing evil. With the beginning of the present war the French and British authorities undertook to eliminate it by the inoculation of the soldiers and the purification of the water.

Water can be purified in several ways, either by removing or killing the disease germs. The first could be accomplished by passing the water through sand, charcoal or some form of porcelain filter, and the second by boiling the water or introducing into it some chemical compound possessing germ toxic properties. Sand and similar filters are efficient only for fixed installations on account of their bulk; porcelain filters are portable but are too frail to withstand battle conditions, while boiling was out of the question on account of the time

involved, plant required and scarcity of fuel. The Water Supply Engineers were, therefore, reduced to use some form of chemical treatment that would kill the germs but leave the water not too disagreeable to the taste.

There were many chemicals that were efficacious against disease germs, but few that met the obviously necessary requirements of being certain in result, reasonably rapid in action, harmless in general character, that did not discolor the water, and that were easy of application even in the field. To show the necessity for the last, there is a British story that during some practical trials one soldier was heard to ask as he held in his hand three tablets that were to be introduced in a certain order, "Now then, Bill, which of these 'ere pills goes in first?" "Lord knows, shove the whole blooming lot in together and 'ave done with it!"

Permanganate of potash was tried, which had a salutatory action through the release of free oxygen. It was very efficacious against cholera germs but not so much against those other bacteria that convey enteric diseases. It had the disadvantage of being slow in action. Calcium permanganate was experimented with, but though good in laboratory experiments, was too complicated for field application and called for filter caps on water bottles. Bromine, iodine and liquid chlorine were all tried. They possessed some advantages but were rejected as failing to meet the requirement of ease in application. Finally there were left two compounds, ordinary bleaching powder and sodium bisulphate.

Bleaching powder had the great initial advantages of low cost, permanence in character and of being an article of regular commercial production on a large scale. Like similar substances it is composed of several chemical compounds, some of which exist as technical impurities, but its principal ingredient is known as calcium-chloro-hypochlorite, whose chemical formula is $CaClO, Cl$. It

was known that chlorine was a powerful and quick-acting agent against bacteria, one part of chlorine per million destroying germs in thirty minutes. Bleeching powder when dissolved undergoes the following transformation:

$$2\ CaClO,\ Cl = CaCl_2 + Ca\ (ClO)_2\ \text{(hypochlorite)}.$$

Hypochlorite has strong oxidizing properties, being converted in calcium chloride and free oxygen thus:

$$Ca\ (ClO)_2 = CaCl_2 + O_{20}.$$

The sterilizing action is due in part to oxidation and in part to the toxic properties of hypochlorite on germs.

Two grammes of bleaching powder of ordinary composition will give 1 1/3 part of chlorine per 1,000,000 parts of water, which is in excess of the required amount of one per million, but it is well to have such an excess to allow for deterioration in the powder or possible excess of impurities diminishing the amount of chlorine present.

It was customary to chlorinate water in the water carts when filled or in the water receptacles in which drinking water was stored. The dose varied from the above minimum to six times the amount, depending on the condition of the water, as water would absorb chlorine in proportion to its own contained impurities. There was a very simple field testing apparatus that quickly gave the amount required. In a large receptacle, such as a water cart, it was well to refrain from using the water for some hours after being treated in order to allow the chemical action to penetrate all parts. In a small container holding a few gallons, reaction was complete in half an hour. Water so treated, especially if the dose were strong, had a slight and not particularly attractive taste, but men did not mind it because the disagree-

able taste assured them that they were drinking water that had been rendered sterile for their benefit.

Sodium bisulphate was another chemical that met the requirements of a satisfactory sterilizing agent, the chief objection being that long continued use might form sulphate of lime, which is insoluble in the alimentary canal. It also attacked iron, copper and nearly all alloys. Of metals that might be used for water containers aluminum was the only one not injuriously affected, but as nearly all water bottles or canteens were made of aluminum, sodium bisulphate, which could be put up in tablet form, made a very convenient and valuable means for individual use when the regular sterilizing apparatus was not at hand. Men who might be thus separated from their main supply were provided with these tablets, one tablet of two grammes sufficing to kill the germs in an ordinary canteen in thirty minutes. The chemical reaction is shown by the formula:

$$2\ NaHSO_4 = Na_2\ SO_4 + H_2\ SO_4.$$

It is the sulphuric acid set free that has the toxic effect.

The disagreeable taste of the acid can be counteracted by making up the tablets with oil of lemon and saccharine.

When the men came to understand that they could drink treated water with impunity whereas plain water, no matter how clear and limpid in appearance, might and probably did carry deadly disease germs, they were very careful to insist on the former.

It was difficult to ascertain and consequently adopt a standard for the minimum amount of water required for troops as the consumption varied between such wide limits, according to local conditions or composition of units. The British made a careful study of these questions because it was necessary for them to have some basis on which to design their larger concentrated water

points. They finally decided that on the average the following figures per man per day gave a fair basis for computation:

Troops living in huts..........	5 gals.
Troops in camps where clothing was washed	5 gals.
Troops in camps where clothing was not washed	3 gals.
Troops in bivouacs	1 gal.
Troops on the march drinking water only, minimum........	$^1/_3$ gal.
Hospitals.....................	10 gals.
Horses per head	10 gals.
Mules per head	6 gals.

The above are rated in British imperial gallons, which should be increased by one-fifth to give figures in U. S. gallons.

The above consumption of water was probably greater than that used by the French. On the other hand it was undoubtedly much less than that demanded by the Americans, who invariably consumed more than either of the other allied armies. The American national propensity for waste was everywhere apparent and it used to be said jokingly that an American unit would waste or unnecessarily consume enough supplies of all kinds to maintain satisfactorily a French unit of corresponding size. That this remark had some justification, in fact, was shown by the comparative expenditures of the two nations.

As it was not until August, 1918, that the Water Department became thoroughly and officially established, it was only in the two great offensives of St. Mihiel and the Argonne-Meuse that it really functioned in the field. The work done by the Water Supply Regiment in those

offensives will be referred to in the chapter describing the results accomplished by the engineers.

The largest single feat of the Water Supply Department was in the Service of Supplies in connection with the large hospital at Mars-Sur-Allier, where a system including a pipe line ten inches in diameter, five miles long, with a pumping plant working against a head of 200 feet and delivering sufficient quantity to supply hospitals with 40,000 beds, was installed in thirty days.

The health statistics of the American army, confirmed by the similar statistics in all the other armies, present eloquent testimony as to the beneficent results of the enforced application of science. Typhoid fever, the great silent enemy of armies, boasting always of more victims than shells or bullets ever did, was banished from the field.

In the Mexican war for every 100 men killed in battle or who died of wounds, 726 died from disease. In the Civil war on the Federal side the ratio for death by disease to death from battle was 200 to 100, while in the war with Spain, the ratio again rose, due largely to the fearful ravages of typhoid even in home camps, and accounted for 85 per cent of the total number of deaths, the actual proportion being as 520 to 100. On the contrary, in the recent war, the proportion was only 36 to 100. Had it not been for the epidemic of influenza-pneumonia which swept over not only the army in France, but the whole world, the last-named ratio would have been much less, perhaps not over 25 to 100. In the whole American army and up to May, 1919, including, therefore, a period of six months after the cessation of hostilities and battle casualties, there were only 2,328 cases of typhoid fever reported with the comparatively insignificant total, when dealing with men by millions, of 227 deaths. Of all causes of death from disease, pneumonia, with which water supply had no con-

nection, was the greatest, contributing 83.6 per cent. To typhoid, the previous scourge, there fell but one-half of one per cent, when expressed as a fraction of the whole, while the actual number of men who died of typhoid was the same as those who died from either peritonitis or Bright's disease, causes that are ever present and never occasion alarm.

The American war with Spain made clear beyond doubt the cause of yellow fever and showed that that disease and malaria as well could be eradicated, so likewise the recent war has proved that typhoid fever need not and should never again be present to a large extent in gatherings of people even under the trying conditions of active war in the field. When the history of the war is compiled, this fact will stand out in high relief as one of the greatest strides ever made in the record of medico-chemical science.

CHAPTER XVI

CHEMICAL ENGINEERS

Although poisonous gases were used for the first time during the war, their employment had been considered on many occasions, but the proposal was rejected each time and by every nation.

During the past century chemists, inventors and even military people had urged their adoption, but no belligerent had been found bold enough to defy world opinion by having recourse to an innovation from which the mind recoiled with horror.

At the meeting of the first Hague Peace Conference in 1899, the matter of lethal or asphyxiating gas was referred to a special committee. When the matter was put to a vote the representatives of the following countries on the committee voted in favor of prohibiting its use: France, Austria-Hungary, Norway and Sweden, Japan, Holland, Denmark, Turkey, Italy and Germany. The American delegate, in accordance with his instructions, answered "No" and placed upon the records the following explanation of his vote:

"1. That no shell emitting such gases is as yet in practical use or has undergone adequate experiment; consequently, a vote taken now would be taken in ignorance of the facts as to whether the result would be of a decisive character, or whether injury in excess of that necessary to attain the end of warfare, of immediately disabling the enemy, would be inflicted.

"2. That the reproach of cruelty and perfidy made against these supposed shells was equally uttered formerly against firearms and torpedoes, although both are now used without scruple. Until we know the effect of such asphyxiating shells, there was no saying whether

they would be more or less merciful than missiles now permitted.

"3. That it was illogical and not demonstrably humane, to be tender about asphyxiating men with gas, when all were prepared to admit that it was allowable to blow the bottom out of an ironclad at midnight, throwing four or five hundred men into the sea to be choked by water, with scarcely the remotest chance of escape. If, and when, a shell emitting asphyxiating gases has been successfully produced, then, and not before, will men be able to vote intelligently on the subject."

The British delegate stated that there was little probability of such an invention but, if there were a prohibition, it should relate only to projectors whose express object was to diffuse asphyxiating gases.

At a second meeting of the Committee on a vote to adopt the proposition for a reference to the conference, fourteen votes were cast in favor of prohibition, only the American delegate voting "No." The subject finally came up before the Peace Conference, whereupon a vote "prohibiting the use of projectiles whose sole object is to diffuse asphyxiating or deleterious gases" was carried unanimously with one exception: the one dissenting vote being that of the United States, although Great Britain's vote in the affirmative was cast on the condition of unanimity.

Relying on the declaration of the Hague Conference, the allies gave no consideration to the employment of toxic gases, assuming that the enemy would observe internationally established and generally recognized humane methods of conducting war. The allies had made no preparations for defense against such an attack. When, therefore, on the 22nd of April, 1915, a yellow cloud was seen rolling slowly across No Man's Land, blown by the gentle easterly wind against the allied

trenches, it raised at first nothing more than curiosity among the watching British soldiers as to what it meant, and then caused horror and consternation as the irritating, choking, killing mist swept over them and they fully recognized the awful significance. There was no escape, men must breathe steadily or die, and now the men at Ypres had to breathe and die. What the losses were has not been published.

The allies understood at once that Germany intended to place no limits on the weapons or means to be employed and that, therefore, it was necessary for them to devise immediately some sort of defense and to turn against the enemy their own fiendish device. In both of these efforts they were highly successful. It seems probable that if a balance of the account could be struck it would be found that the Germans were, on the whole, heavy losers by the use of gas, especially as the blockade seriously interfered with the importation by the central powers of certain highly necessary raw materials used in the manufacture of both gases and protective masks. Sometimes one wonders whether the Germans, having decided to employ gas, could not have manufactured and had on hand such a supply that they could have made attack closely following attack, and so actually have forced their way to Paris before the allies were able to improvise masks for defense or make the gas itself with which to return blow for blow. Was this another opportunity to reach Paris that was presented to the enemy that he neglected to use? At the moment it appears so, but perhaps some day when all the facts are available, another generation will learn definitely.

The gas used in the Ypres attack was chlorine, one of the two constituents of common salt, out of which it is manufactured by electrolytic process. It has a greenish-yellow color with a very irritating and suffocating quality. The effect on a person breathing it is violent

choking and, if taken in sufficient concentration, serious inflammation of the respiratory organs by its irritating property, causing an outpouring of mucous in the lungs which frequently results in death as from drowning, or else so irritates them that severe and long continued bronchitis or pneumonia results. While chlorine gas was easily manufactured, it was not very satisfactory as a weapon of offense on account of its volatile nature and quick dispersion. Studies were, therefore, made to produce gases that were both heavier and more deadly.

Of gases of this type, the two chief examples were chlorpicrin and phosgene. The former was the next gas made following chlorine. It is a combination of chlorine and picric acid and is a strong poison, attacking both eyes and lungs. The fact that it injured the eyes, rendered useless the first respirators, which were simply mouthpads soaked in a solution of hypochlorite of soda. Phosgene, on the other hand, is a chemical combination of chlorine and carbon monoxide ($CO + Cl_2 = COCl_2$) and is the most deadly of all the gases that were used. On account of its slight odor, its presence was scarcely recognizable and the effect on men breathing it was most insidious, for although its main attack was on the lungs, it also affected the heart, so that men who had had small doses might suddenly drop dead without knowing that they had been subjected to phosgene. It was, therefore, ordered that, whenever men knew that they had been exposed to phosgene, they should lie quite still until removed on a stretcher or in an ambulance. These gases when under pressure or at a temperature of about 32° F. became liquid and as such were loaded into shells and cylinders. When allowed to escape at atmospheric pressure they became gases which were heavier than the air.

Although chlorine was sometimes used, chlorpicrin and phosgene were relied on when deadly effects were

desired. So terrible was phosgene that one full deep inhalation was sufficient to cause death. But, even if death did not result from an exposure to chlorpicrin and phosgene, a man's whole respiratory apparatus was seriously injured. If the injury were not actually permanent it sufficed in many cases, depending on the amount of poison inhaled, to disable the sufferer from active duty for months, rendering him susceptible to pneumonia or other pulmonary diseases, and leaving him for a while as one afflicted with tuberculosis. A soldier in such condition was, so far as the enemy was concerned, better than one dead, as he not only ceased to be a belligerent but actually became a burden.

The treatment of serious cases of chlorpicrin or phosgene poisoning consisted in general of insisting on absolute avoidance of muscular effort, followed by bleeding of the patient and with an injection of a salt solution. The amount of blood withdrawn might be considerable, being in extreme cases as high as one and a half per cent of the body weight. Oxygen was administered and also stimulants like brandy, the patient being kept warm and. so far as possible, in a well ventilated place.

In addition to the lethal gases, others were developed which when used alone produced only discomfort. Of these the first to be employed were the lachrymator or tear gases which irritated the eyes in such a manner as to cause almost immediately a great discharge of fluid, involving much pain and temporary blindness. They were more cheaply produced than phosgene and although not fatal, were exceedingly useful when projected against the first-line fighting force and especially the artillery, because even a trace of tear gas rendered a man blind and, therefore, quite useless for a short while. These tear gases had a bromine base, the commonest form being brom-benzyl-cyanide.

Later the Germans produced a new gas that attacked

externally as well as internally, the famous mustard gas, so called not because it was produced from mustard or had any connection with it, but because it had a somewhat similar odor and produced precisely similar burns. Chemically speaking, it was di-chlor-ethyl-sulphide, manufactured by blowing gaseous ethylene into sulphur monochloride. The Germans made a great blunder in using this excellent means of causing human suffering, because the Allies promptly began to use it, too, and in spite of boasted German excellence in all matters chemical, the Allies were able to manufacture it in a far larger quantity than the Germans could. In fact, the War Department report on American Munitions states that on the conclusion of the war the whole German capacity for turning out mustard gas was only six tons a day as against an American capacity alone of ten times that amount, with a large British and French output in addition. Mustard gas presented many advantages over phosgene even if it were not so deadly, although it was fairly satisfactory in that respect. It was a liquid, stable at ordinary low temperatures and volatile at higher temperatures, with an odor in the open so slight as to be recognizable only with difficulty. Ground saturated with mustard gas would continue to give off vapor for many hours after its receipt, perhaps for several days if the weather were cool and the ground sheltered from sun or wind. Troops might be moved into an area which, quite unknown to them, had been "gassed" with mustard sometime previously and actually sit down in an atmosphere that would presently cause casualties, and not be aware of it until the casualties began to appear, especially as this gas did not give a choking or other warning as did the chlorine compounds. Although it attacked the bronchial tubes and respiratory organs and caused many deaths by pulmonary disease, when it was a novelty and proper treatment

was unknown, its most usual effect was exceeding painful surface burns, which occurred most acutely on those parts of the body where there was the maximum of perspiration. Such burns would completely disable a man to the extent of keeping him in the hospital for weeks. The internal effects of mustard gas or the external burns were frequently severe enough to cause death even after the nature of the attack was understood, but it was noted that while there was no difference between the injury produced internally on whites and negroes, it was found that the latter were markedly less sensitive to skin burns.

When the first wave of gas was projected against the allied trenches, our friends were without any protection. One quick-minded and ingenious quartermaster of a British division took the first step in defense by supplying his troops, within twenty-four hours after the first attack, with a pad of several thicknesses of cotton cloth soaked in hyposulphite of soda which gave them fairly good protection for a short time. For this he was rewarded with the coveted Distinguished Service Order. But the matter was so obviously threatening that it was immediately taken up for serious study by both the British and the French. Until perfected apparatus could be devised, the men were provided with simple respirators capable of absorbing the deleterious properties of chlorine gas, the only one used at first. But as the enemy began to vary the gases and especially to use gases that attacked the eyes, the allies were obliged to discover more efficient and more complete means of protection not only against the chemical action of the different gases, but also as a covering for the whole face. The investigations and experiments were conducted with the view of devising a headgear that would protect the eyes, cover the very sensitive parts of the face and permit the wearer to breathe a steady supply of purified air. Such a headgear was unavoidably awkward and uncomfortable, but

nevertheless a form had to be found that would cause the least inconvenience, and one that men could wear and even work in while wearing it for hours at a time in a gas-laden atmosphere where but a few inhalations meant death. The designing of the apparatus was quite as complicated a problem as finding the most satisfactory chemicals to absorb or nullify any gas likely to be used before the air carrying it could reach the men's lungs. Even the fabric out of which the headgear should best be made required special study because so many substances were subject to decomposition by the action of the gases. All this makes a fascinating story in itself. The investigations called for the most intense study on the part of the master chemical engineers of Great Britain and France, and later of those of the United States.

As the result of the first experiments in the laboratory and practical tests in the field, troops were furnished with two types of anti-gas protectors, a helmet consisting first of one and later of two thicknesses of flannel soaked in a solution of sodiumphenate, caustic soda and glycerine, which could be drawn quickly over the head and gave some protection against weak gas for a short while, and an air-tight mask fitting the face closely and preventing any external air from reaching the lungs except through the protected mouthpiece.

The helmet was used by both the French and British armies and for a while by our own as a secondary means of defense, but in the year 1918 it was discarded as not being satisfactory. It was nothing but a loose bag with the open lower end tucked in under the wearer's coat, air being drawn in through the porous material. There was an unavoidable leak and the efficacy of the chemicals began to fail after short exposure, against which the advantage of its lightness and ease in adjustment weighed but little, especially as every soldier was obliged to carry also the more perfect equipment. It

was soon discovered that with the helmet respirators, artillery was practically out of action where gas was present. This necessitated the development of some other protection and the result was the box respirator. The first form was quite cumbersome and too heavy for infantry to carry but as its protection was nevertheless excellent a smaller and lighter model soon appeared.

The mask or small-box respirator, as it was sometimes called, consisted of a rubberized fabric covering the whole face and held in place by elastic bands passing behind and over the head. Air for breathing was drawn into the mouth through a mouthpiece held between the teeth, whence there led a flexible pipe to a canister containing gas-absorbing chemicals. The breath was exhausted through the mouthpiece, whence it escaped through an automatic valve. Breathing through the nose was mechanically prevented by a clip attached to the inside of the mask which closed the nostrils by compression. Any gas that might find its way behind the mask could not, therefore, reach the lungs. There were two large eyepieces of a non-breakable glass. The whole apparatus was carried in a square canvas bag slung over the neck but hanging on the chest when in the position of "alert," or ready for immediate use, and held against swinging by a cord tied around the body. Men were trained so that the mask could be withdrawn from the bag, put in place, nose clip adjusted and mouthpiece inserted in less than ten seconds. That was the maximum time allowed, and no man was passed through his gas-training course until he could accomplish the operation in that time. When the men became expert, all the steps could be completed in five or six seconds. The chemical containers remained in the bag. The dimensions of the latter were about ten inches square and three inches thick and the whole apparatus weighed a little more than three pounds.

The training in the adjustment of the respirators was carried out in the presence of lethal gases, the men being taken into closed buildings filled with gas. Besides learning how to put on their respirators quickly and receiving an explanation of the dangers due to gas, they were convinced by practical tests that absolute safety was afforded by their respirators. This added greatly to their morale when exposed to the same fiendish forms of barbarity in the field.

It is not an exaggeration to say that these contraptions were exceedingly disagreeable, but men could work and actually sleep in them. The discomfort was offset by the knowledge that, thanks to the skill of the chemical engineer at home, the wearer could live in an atmosphere that would cause death in a few minutes without them. So great was the advance and perfection in manufacture that, while the earlier types of mask became inoperative in a few hours through the exhaustion of the absorbing chemicals, those that were being produced at the close of hostilities had a working life several fold greater.

The active part of the mask respirator was the absorbing chemicals which removed the toxic gases as the poisoned air was drawn through the container by the act of inhalation. Carbon was known to be an excellent absorbing agent. The difficulty was to secure a form of charcoal having a great density, as that gave the maximum of absorptive power for the minimum of weight, with hardness to resist breaking into dust that might clog the interstices of the mixture in the canister and so reduce its air-passing capacity. All kinds of material were tested, hundreds of varieties in number and from all parts of the world. But after experimenting, by the aid of a large staff of chemists, with almost every conceivable vegetable substance, the unsuspected cocoanut shell stood out as nearest to the ideal.

When the United States took up the making of masks

and decided to use cocoanuts as the basis for the supply of carbon, it was estimated that an amount of forty or perhaps fifty tons a day would suffice. As the demand increased, this figure was constantly raised until finally it reached 400 tons of shells or the equivalent. Now the total supply of cocoanuts from the West Indies, Central America and the northern coast of South America amounted to only seventy-five tons a day. The above countries were necessarily the main source of supply, because lack of ocean tonnage prevented extensive importations from the far East. Then it was found that the shortage in home sugar supply reduced candy and sweets manufacture, and consequently curtailed cocoanut consumption. This unexpected turn forced the government, firstly to start the famous "Eat more cocoanuts" campaign to stimulate the production of shells and, secondly, to find the most satisfactory substitutes. Among the latter, various nuts and fruit pits, including those of the peach, apricot, cherry and plum, were discovered to be reasonably satisfactory. These were obtained from the canning establishments and through collection receptacles placed in the streets.

Mixed with the charcoal were particles of a special lime cement to neutralize the acid quality of certain gases, sodium hydroxide to give increasing alkaline effect and sodium permanganate for its oxidizing property. When this mixture had absorbed its quota of poison, the canister was removed and a new one substituted. This change of canisters was regulated by having every man record on a slip attached to his mask the hours of exposure and, when a fixed limit of forty-eight hours was reached, to have the canister exchanged.

Horses also had masks, but here, fortunately, the problem was much simpler than with their human riders or drivers. It was found that horses' eyes were not affected by tear gases, and that to toxic gases they were much

less sensitive than men. As the horse always breathes through his nostrils and not through his mouth, all that was necessary was to provide a loose porous bag of heavy soft material soaked in neutralizing chemicals that could be drawn over his nose, leaving his mouth free for the bit.

Gas waves as first projected at Ypres were discharged from steel cylinders, the gas being allowed to escape from nozzles and be carried down wind towards the allied trenches. This was the only method employed for some time by both the Germans and the Allies. Such a method was open to many serious objections. The large cylinders were cumbersome, taking some time to put in position, and as the wind was the only propelling force, this position had to be as advanced as possible. As a matter of fact it had to be in the very front trench, because obviously the gas wave could not be allowed to pass over one's own men.

As action depended entirely on the wind, and that must be exactly right — not only as to direction but also, as to force, gentle rather than strong — the actual loosing of the gas might have to wait for days for favorable weather conditions after the cylinders had been set in place. During this period the cylinders not only filled the trenches to the inconvenience of the defenders, but there was danger that they might be discovered and so give warning that a gas attack was imminent, or some might be damaged by shell fire, freeing the contents among the very men tending them. In the event of the discovery, an immediate bombardment by hostile artillery would certainly result.

A further objection to cylinders was that the element of surprise so essential to success was absent or nearly eliminated. When gas and the methods of its liberation were understood, the commencement of a wave attack was easily recognized even at night, when

nothing could be seen, by the sound of the escaping gas. As the best wind was a gentle one with a velocity of about five or certainly not exceeding ten miles an hour, so as to avoid disturbing and scattering the cloud, an interval of time of about fifty seconds would elapse before the wave travelling at the higher velocity reached the opposing trench, even if it were only 250 yards away. This time, short as it was, sufficed to permit an alarm to be spread, and for men even in the front trench opportunity to adjust their masks. Men farther back had still more liberal warning. Furthermore, the strength of the gas was entirely dissipated three miles from the point of origin. Then finally there was the danger that, after a cloud had been started, a sudden change in wind might occur and the whole nasty mess come rolling back, an accident that was of actual and not infrequent occurrence.

These objections started both sides to devise means of firing gas from guns. Although gas clouds liberated from cylinders were up to the end of the war sent out occasionally under very favorable conditions, main reliance was placed on gas-laden shells which both sides soon learned to manufacture and fire with great success.

Gas shells were made with thinner walls than ordinary shells so as to provide the maximum gas-holding capacity. They were given a bursting charge of some high explosive just sufficient to break the case and free the gas contents. By means of shells a gas attack could be made at any time regardless of weather and could be directed on any part of the enemy's territory — either the front-line trenches or among the reserves as far back as the guns could reach. Such an attack could be made suddenly without warning. Under these conditions no one within four or five miles of the front was safe against gas attack at any moment. Within that distance it was ordered that gas masks should always be carried.

Gas shells, on account of the smaller bursting charge,

made a much lower toned report than that of ordinary high explosive shells and, therefore, were easily recognized. To disguise the use of gas shells, it was customary to send over gas and high explosive shells at the same time and so drown in the mingled roar any difference in sound between individual bursts. Or the ratio of the bursting charge to the gas content might be increased so as to make the bursting sound more nearly like that of an ordinary shell. While the latter course would diminish the amount of gas liberated, the smaller amount would be highly efficacious if the enemy could be caught unaware of any gas being used.

Gas projected in shells had a much longer range than when discharged from cylinders. It could be thrown into back areas or in scattered and unsuspected attacks. Therein lay an additional advantage in the use of chlorpicrin and phosgene over chlorine, as their more stable character delayed the dissipation of the gas. Tear, sneezing or vomiting gases were usually projected just prior to the discharge of chlorpicrin with the hope that some might be caught by the former and either could not get their masks on or, in desperation tear them off, when the sufferers would receive the full effect of the lethal gas. The tear gases were particularly effective in this, as a very minute amount, too small to be otherwise noticed, would injure the sight for several hours.

The gases in liquid form had another damaging character in that drops might be spattered over wounded men's clothing and would continue to vaporize for some hours. Many casualties have thus resulted from soiled clothing being carried into confined sleeping quarters or to other men tending wounded, and even among doctors and nurses in hospitals working over men that had been gassed as well as shot, whose clothes were, perhaps quite unknown to them, gas polluted. The heavier gases would flow down into shell holes or dugouts and lie there for

hours before becoming dissipated. Curtains made from blankets soaked in or sprayed with a solution of sodium thiosulphate (1½ lbs.) and sodium carbonate (3 lbs.) to three gallons of water, hung in front of dugout entrances furnished some protection.

Besides discharging gas in shells from long-range guns, it was also thrown in hand grenades and in various forms of shells fired from trench mortars. Of the latter, the most effective was the Livens projector, something like an old-fashioned, smooth-bore mortar, except that it was longer and lighter in the barrel. From it were fired cylinders twenty-four inches long by eight inches in diameter, with an effective range of about one mile. As the tubes and cylinders were easily and cheaply made, large installations could be collected and a great volume of gas liberated in a few minutes. The hand grenades contained poison gases and also phosphorus gas, producing smoke clouds and fires.

When the United States entered the war, chlorine gas was the only gas of the toxic variety that was produced on a commercial scale in this country, and even the whole product was quite insufficient to meet the suddenly increased demand for war purposes. The government was obliged to create a plant with a daily capacity of 100 tons of liquid chlorine. Although chlorine alone was little used, it formed an important part of the composition of other gases, notably chlorpicrin, phosgene and mustard.

The American gas output began in January, 1918, with ten tons, while in the month of October more than 2,700 tons were accepted, with a total of nearly 11,000 tons before the 11th of November. To transport this huge amount there would have been needed nine trains of tank cars, each train being one-half of a mile in length.

Between twenty and thirty per cent of all American

casualties were due to gas, the greater part fortunately being light.

So great was the importance of gas work that a separate corps was established called the Chemical Warfare Service, to which the Thirtieth Engineers were transferred as the first Gas Engineers.

Arms and all equipment made of steel were subject to the evil effects of gas quite as much as men and beasts. To prevent corrosion, rifles had to be kept oiled, but as that was not always possible it was ordered that, when a gas attack was in progress, rifles and machine guns should be fired occasionally to insure their not jamming. When the attack had passed they were to be taken down, thoroughly cleaned and oiled. Even ammunition and the working parts of hand grenades were effected and had to be protected. In short, very little escaped the injurious action of this terrible, insidious, searching fiendish agent.

CHAPTER XVII

CAMOUFLAGE AND OTHER FIELDS OF ENGINEERING

In addition to the large fields of activity, such as transportation, general construction and the more delicate work in electricity, chemistry and physics, where engineers had the opportunity to apply their science on a broad scale, there were other fields where, if the men employed were not numbered by the tens of thousands, if their accomplishments were not so spectacular, they, too, formed an important link in the work of the successful conduct of a modern army.

The first of these was the telegraph and telephone system. When a battle front is continuous for 400 miles and an engagement under the direction of one man covers perhaps fifty miles, it is obvious that no longer is it possible to rely even in part on the old methods of sending orders by orderly, courier or some form of hand signals. Consequently in the war just ended, the telegraph and telephone became of transcendent importance and were used more extensively than ever before, practically superseding all other methods of sending communications except the slow one of courier post for bulky letters or for those not urgent. Telephone wires placed every camp, every headquarters-dugout, even posts in the front trenches, as well as the important points in the rear, in instant communication with each other.

This work, although of an engineering nature, was taken care of by the Signal Corps and not by the Corps of Engineers. But the subject cannot be left without comment, even if the work was not performed or the service maintained by the Engineers, without at least recording that the American telegraph and telephone system,

of American material with wires strung by American troops, made a network over a large part of France. It included within its meshes the base ports of entry, the many supply depots, concentration camps, the main headquarters at Chaumont, Paris and Tours, and the headquarters of the various armies, corps, and divisions, as they were found in the field. Then as the final advance progressed, the lines were extended to keep in touch with the ever-changing front. To construct and maintain these lines an appalling amount of material had to be shipped to France, of which the one item of line wire and cables amounted to no less than nearly 150,000 miles, or sufficient wire to stretch six times around the earth.

The English language always stands ready to absorb any improving modification. As the result of the war it has taken many additions to its vocabulary of which undoubtedly a large proportion will be permanent. In this process of change even the alphabet did not escape. We are all aware that several of the letters have a similar sound, leading both to confusion and error, when spoken over the telephone. Some British genius, whose name ought to be recorded, removed the difficulty by giving new names to those letters that might be mistaken. Thus ACK stood for A, Beer for B, Don for D, Emma for M, Pip for P, Esse for S, Toc for T, Vic for V, while the last letter of the alphabet was always called by its regular English name Zed. The other letters retained their accustomed sounds. So thoroughly practical was this innovation that it was adopted by the American telephone operators in large part, and would have become universal had the war lasted longer and more men had become familiar with it.

The British always, and the Americans usually, abbreviated all names to the initial letters. Some of these combinations were easily recognizable, like G. H. Q. for General Headquarters, or O. C. for Officer Commanding,

but some, like D. A. D. O. S., were not quite so readily legible. This last combination was not to be confused with the dodo, the extinct form of bird, but described a simple-minded sort of person performing the duties of a Deputy Assistant Director of Ordnance Supplies. So firmly was this method of abbreviation rooted that even in ordinary conversation there would be used the initial letters and not the words themselves describing an officer, place or some article in common use, and frequently the letters would be given their new names. Thus an observation point, which was always spoken of as an O. P., was called on "o-pip," while a trench mortar, shortened to T. M., became a "Toc-emma."

But if the main telegraph and telephone lines were in the hands of the Signal Corps, some electric wires were installed and maintained by the engineers. In addition to their work in range finding the Seventy-fourth Engineers took care of the "listening-in" sets by which enemy telephonic conversations were overheard. The front-line telephone system was at first a single-wire line, the earth being used for the return circuit. But a French engineer devised an instrument called a geophone, which was afterwards so improved and developed as to have a greatly extended field of usefulness. In principle the device consisted of a drum in which the enclosed air space received the sound waves, magnified them and by electro-mechanical apparatus transmitted them to any conveniently located listening station. As finally perfected these instruments were sufficiently delicate not only to catch sounds transmitted through the air, but to give notice of raiding parties operating at night between the trenches, and even picking up low-toned conversations between the enemy lines. With several such mechanical ears open, it was possible to locate enemy movements in the dark by simply noting the relative intensity of noise on the several geophones.

These instruments, of course, even in their first comparatively crude form, could easily catch the return current from a single-wire telephone or telegraph system. This forced the installation of double-insulated wire lines on which the return current could not be tapped as the ground return could be. But the man of science was not to be beaten. By making his geophones more delicate he was able to overhear the actual conversation behind the enemy lines as spoken into a telephone receiver, provided only he could place one of his little mechanical ears, which, with its connecting wires, was a most inconspicuous object, close to the enemy trenches.

The setting of these boxes at night in No Man's Land was a nerve-testing task. On one occasion as an engineer was returning to his own lines after attending to his instrument, he was suddenly stopped by a challenge from a negro sentry in the firing trench whom he had aroused by the noise he made as he stumbled over the body of a dead German.

"Fo' the land's sake; what yo' all doin' out yonder?" asked the negro, but all the while keeping him covered with his rifle.

When the member of the Seventy-fourth Engineers explained who he was and what he was doing, the darky lowered his gun, told him to advance, saying:

"The Lawd be praised, but I certainly is pleased I don't belong with the engineers."

In one American division there were some Cherokee Indians who, in order to overcome the danger of having telephone messages overheard and understood by the enemy, were employed as telephone operators in the front trench. When the message was received at headquarters it was there translated back into English. What pains the Germans must have taken, with their accustomed thoroughness, to discover the key to this extraordinary code!

These geophones had another application. Both sides carried on extensive underground operations in driving tunnels beneath the other's positions, filling the leading chamber with high explosives and then blowing up a great section of trench or a strong point at the critical moment of an attack. The geophones would give warning by noting the sound of pick or drill underground even at a distance of seventy-five yards. By employing two geophones on the binaural principle and changing their position until the intensity of sound was the same in each ear, the direction whence sound came was determined. The intersection of two such lines of direction gave the exact spot where work was being executed. Then the tunnelling engineers would be called on. A counter gallery or tunnel would be driven and the enemy attempt frustrated.

As facility and extent of observation by airplane were increased and the accuracy of indirect fire developed, it became necessary to hide or screen guns, ammunition and troops. When the war began the French army wore the old and well-known scarlet breeches, which made a wonderful display to airplane observers and were the cause of many casualties. From such experiences both sides soon realized that observation from above had begun a new era, and that men must do as the wild animals did and render themselves inconspicuous. Sombre uniforms that lacked distinguishing contrast were adopted, glistening gun barrels disappeared under paint, even the bright parts of men's accoutrements were covered. But this was not enough. Masses as well as details had to be obscured, and a special corps headed by experts was organized to create what was more than an art, almost a science, to which was applied the French name of "Camouflage."

This word, which has become firmly rooted not only in French, but in English and probably other languages,

is, like tanks and very long-range guns, a product of the war. Dictionaries of a date earlier than 1914 do not contain it, and there is considerable doubt whence it came or how it was introduced. The nearest approach to it was "camouflet," which had quite a different meaning, a puff of smoke blown in the face, or in a military sense, a small mine. Apparently camouflage comes from old Franco-Provençal stock and was drafted into the slang of thieves in Paris under the form of "comoufle," meaning disguise, whence it was taken up by the artist community and popularized by them in the form now known.

The basic idea of camouflage was to hide men or objects from observation, either by giving them a mixture of colors so that they would blend with surrounding objects, or by so destroying their apparent outlines or confusing the outlines with the shadows that they cast, as to prevent or interfere with recognition when viewed from a distance and especially at a distance from above.

To obtain concealment by actual hiding was usually impossible, especially for the most important objects — men, guns, piles of ammunition, or special buildings. Any covering sufficiently large to hide such objects would in itself be visible. It was, therefore, necessary to have resort to the more subtle phases of the art. In the discovering, studying and applying the colors or imitations that would deceive or mislead rather than hide, there was ample room for unlimited exercise of human ingenuity.

The dun color of the regulation olive drab uniform rendered men quite inconspicuous provided they did not look up when an enemy plane was passing. If they did, their white faces showed in the photographs but more particularly to direct observation. Men were, therefore, ordered to restrain their curiosity when "Fritz" was overhead and to refrain from looking up. Men lying down were practically invisible, so well did the color of

their uniforms lose itself in the color of the ground. Men, if standing, cast shadows which were visible, especially to the eye of an aerial observer if the men were moving. He could more easily recognize what a moving shadow meant than a stationary one. Bright mess kits, naked bayonets, or tools polished by work reflected light and called attention to the probable presence of men even when the latter were not visible. Suspected presence of men was almost certain to draw artillery fire which, as will be explained later, could be directed with extraordinary accuracy on a target invisible from the guns. Although strict orders were issued as to conduct by troops in all such matters, they were always difficult to enforce, especially such simple ones as that faces should not be raised or that shovels be carried in the hand blade down and not over the shoulder.

For misleading concealment chief recourse was had to color, the object to be hidden being painted with great irregular patches of contrasting colors, whites, blues, yellows, blacks, in such a way as to destroy the outlines, to accentuate depressions, to tone down parts that would ordinarily show high, and to confound all objects with their shadows. This offered great scope in the practical application of color, not only as the colors gave a false expression to the human eye, but as they would be recorded on a photographic plate. This naturally created a branch of warfare in which artists and color students excelled.

Everything was painted, buildings, tents, guns, wagons and especially covered wagons, railroad cars that loaded with ammunition serving railway artillery might be standing for days at a time on some siding, and sometimes even the steel helmets of the men were decorated, although the last was a needless refinement.

The author recalls some of his tents that would have taken prizes in any exhibition of cubist art. Speaking

of tents it was hard at first for American officers to free their minds from preconceived ideas as to what a military camp should be and to cease placing tents in straight and regular rows. Such an arrangement no camouflage could conceal.

If covering as a whole was impossible, and undesirable had it been possible, covering in part was freely resorted to. The material most used for such purpose was tree boughs, which thrown over freshly turned earth from trench excavations that it was desired to conceal, over guns, or piles of ammunition, so broke the outlines, hid the natural color or confused the shadows as to render detection impossible or extremely difficult. But boughs were not always available. To take their place wire netting was used or nets were made of cord, in the interstices of which were woven pieces of painted cotton cloth resembling leaves or clods of earth. Such screens, hung on poles over guns, gave excellent protection but still permitted the gun to be served. The fact that the horizontal screens might be transparent in spots heightened their efficacy, as they failed to throw a definite shadow or show a marked outline. Similar screens were hung vertically along the side of roads exposed to observation from enemy balloons, cutting off the view of troops so that they could pass behind the shelter of the screens without much danger.

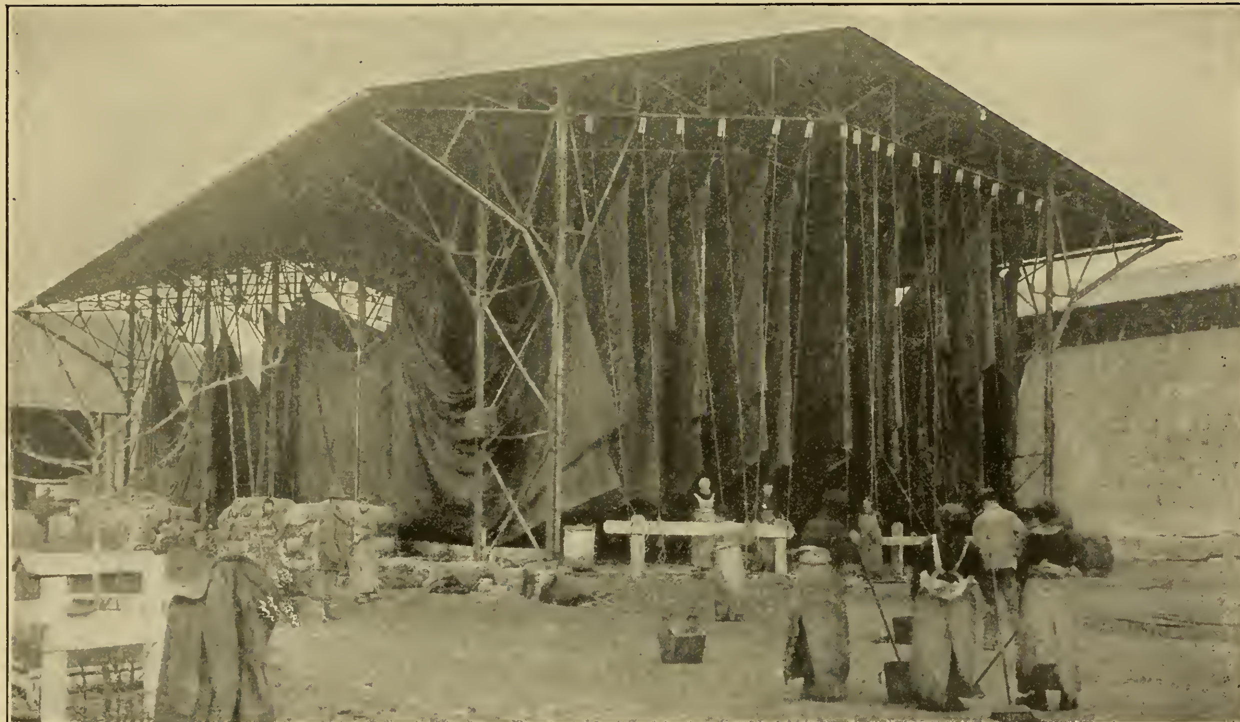
The making of all these articles became an important industry; and for their production the A. E. F. established a well-equipped shop at Dijon, where much valuable assistance was given by the British and French camoufleurs. This shop was managed by the Fortieth Engineers, who employed a large staff of women to assist them. Here there were manufactured wire netting, fish nets, garlands, hangar covers, sniper suits for men to wear on sniping out-post duty, painted burlaps and coco mattings.

The amount of such material produced was very extensive, aggregating, in eight months during 1918, 3,000,000 square yards, or nearly one square mile in area. In addition there were made and sent to the front observation posts, imitation shell holes, dummy heads, and other articles intended to produce a visible effect of something that did not exist instead of concealing what did exist. Sometimes the best concealment is obtained by drawing attention to an illusion.

So important was camouflage that recommendation was made that specially trained camouflage troops be attached to each battery whose duty it should be to mark out paths and roads, to fix the location and to hide the piles of ammunition, and by painting or otherwise to disguise the guns, latrines and kitchens; in short, to study the best means of concealing each gun and to see that an intelligent plan was carried out.

In the St. Mihiel offensive guns and ammunition moved, into position just prior to the attack, were camouflaged with boughs or fish nets. After the attack began and until the offensive subsided, the troops were compelled to maintain the camouflage. The Germans had accurate maps of the whole country, especially of that part that they had only recently occupied but had been forced to evacuate, and they were thus able to concentrate an accurate fire on any point where their airplanes or balloons reported the presence of artillery. In the Argonne-Meuse offensive the movement into position was made only just before the attack began. After the battle commenced the concentration of artillery was so great, not only locally but on the whole front, and the fire so continuous both night and day that little attempt was made either to conceal or to deceive. Guns were stood in the open and there served.

To install electric light and power plants, to care for and operate engines and pumps for water supply and to



FRENCH CIVILIANS PAINTING CANVAS COVERS IN AMERICAN CAMOUFLAGE SHOP AT DIJON

do many things of a mechanical nature for armies and corps, an electro-mechanical section was established and the Thirty-seventh Engineers assigned as the Electro-Mechanical Regiment. Subsequently this regiment was attached to the First Army, A. E. F.

Prior to the beginning of the American offensives, the Electro-Mechanical Section set up a number of electric light and power plants in the Service of Supplies, chiefly for lighting hospitals, storage yards, warehouses, docks, bakeries, refrigerators and other similar institutions, and the furnishing of power to small machines. In some cases the Electro-Mechanical Regiment obtained current from French sources, in others they erected their own generating plants. This work did not differ from electro-mechanical installations under ordinary commercial conditions. In the distribution of the current about 125 miles of transmission lines were strung.

With the First Army the greater part of the service rendered by the regiment was in arranging during the Argonne-Meuse offensive for the mechanical parts of water supply systems, such as large pumping installations, and in providing lights for various headquarters through small mobile installations, the plants ranging from one to 200 kilowatts each, average about twenty kw. It was found that the units ranged in capacity as follows:

Army headquarters..........	10 kw.
Evacuation hospitals.........	10
Corps headquarters..........	5
Division headquarters	3
Brigade headquarters........	1
Hospitals..................	5 to 25 kw.

Experience showed that a whole regiment was an unnecessarily large body to be attached to an army for

electro-mechanical purposes, and the men were detailed for other work. A smaller body of experienced mechanics, if assisted by ordinary engineer troops, would have been more economical. Another reference to this point will be made in a subsequent chapter devoted to the discussion of the best organization of engineer troops.

Electro-mechanical troops were used by the French with great success in keeping certain wires in the entanglements in front of the trenches charged with deadly high-tension currents. Sometimes barbed-wire fences were electrified but the most satisfactory device was an independent plain wire. This was stretched irregularly in plan from tree to tree and from it were dangling wires at about fifty-cm. (20 ins.) intervals and reaching to within perhaps twelve inches from the ground. The main wire was about three m. (9 to 10 ft.) high and, therefore, above the plane of ordinary vision. These wires were absolutely invisible at night and almost so by day. The main wire was charged with a 1,500-volt current. If a person came in contact with one of the loose wires he at once established a ground through his body and was either instantly killed or effectively disabled for a while. Sometimes traps were constructed with barbed-wire entanglements so placed that raiding parties were hemmed in by lines of barbed wire, perpendicular to the front, which either were electrically charged or by their position forced the enemy patrols to advance against a net of charged loose wires. In all such work the French were particularly skillful, especially in concealing the electric trap.

Such a protection could be used only on a quiet sector. If there was much artillery activity the lines would be cut so often by shells as to deprive them of any reliability. The largest installation was on the French front

between Baccarat and Hartmanswillerkopf, a "quiet" sector 150 km. long, of which approximately one-third was protected by charged wires.

The Germans tried to do the same thing, but they were not nearly so successful as the French. This was due partly to their lack of equal skill and delicacy in attaching and hiding the obstructions, but chiefly to their extraordinary obsession for conducting operations on a fixed methodical time table, an obsession that they displayed with respect to artillery practice and other movements, but always with failure to inflict loss commensurate with the expenditure of effort. In the case of electric traps they did not keep the wires continuously charged with current but only during fixed intervals. The French made a study of the method followed on different parts of the front and having discovered the key, sent out experienced electricians who would cut the wires during a dead period immediately previous to any contemplated raid or patrol reconnaissance by French forces.

The Transportation Department had its extensive shops for repairs of rolling stock, the section of Light Railways and the Motor Transportation Corps had theirs. The Chief Engineer soon foresaw that in addition to the above he would need a shop where there could be repaired the miscellaneous equipment belonging to the engineers and not covered by any one or all of the above. As indicating the necessity for such a shop, the following items of heavy engineering equipment were on hand, which had to be maintained and repaired. In the matter of repairs, war service is not conducive to the easy keeping of mechanical plants in good working condition and, therefore, there is all the more need for well-equipped shops.

Some items of American engineer plants on hand in France prior to the 11th of November, 1919, were:

Steam shovels	59
Pile drivers	35
Concrete mixers	350
Locomotive cranes	125
Gas-electric generators	1,600
Motors	700
Pumps, hand	10,000
Pumps, power	1,600
Gasoline engines	600
Air compressors	150
Derricks	300
Boilers	200

A shop section under the control of the Director of Military Engineering and Engineer Supplies (D. M. E. and E. S.), an officer on the staff of the Chief Engineer, was organized in December, 1917. Later the Twenty-fourth and Thirty-fourth Engineers were assigned as shop regiments.

The first step in construction was a shop erected at Is-sur-Tille equipped with such machine tools as could be purchased in the European markets. This original building was a very modest little affair, being only fifty feet wide by 125 feet long, but it did good service, soon beginning to deliver newly constructed engineer equipment urgently needed for the spring operations.

In the meanwhile the engineer officers in command of the section were studying the question broadly and recommended the establishment of a large shop to be erected at the principal engineer depot at Gievres, where all engineer shopwork for the Service of Supplies could be attended to. The extension and application of the Is-sur-Tille plant to work for the Zone of the Advance and, what was equally important, the acquisition of several independent shops, some of which were to be mobile,

for each army was also recommended. The plans for the main shops at Gievres and Is-sur-Tille were laid out on the same general scheme to consist of a group of six buildings each fifty feet by 500 feet. By November, four of these buildings and in addition a large foundry where brass as well as iron castings were made, were erected at Gievres and put in operation. At Is-sur-Tille, while the first shop established was retained in service, a second building sixty feet by 400 feet was erected, consisting of the steel-frame work of an unused bakery building. A small shop was also established at St. Sulpice, the assembling point for engineer matériel on its arrival in France.

Each army shop consisted of a semipermanent metal and wood-working shop with a number of mobile outfits on motor trucks. These latter were composed of four units, consisting of machine, blacksmith and wood-working shops and a material supply car, each being mounted on a five and one-half-ton motor truck chassis. The machine shop truck contained, among other things, a work bench, a drill press, a portable electric drill, a grinder and a fourteen-inch lathe. The blacksmith shops contained work benches, forges, pipe-fitting tools, welding outfit, while in the wood car were drills, saws and grinders. All had their individual gasoline-driven power plants and full complements of small tools. The machine shop truck cost $8,500 and the carpenter shop $7,600, including equipment. These mobile shops were able to do a wide range of repairs and even construction work in the field. On account of their great mobility, they could be run rapidly to the points where needed and thus could and did render exceedingly efficient service. In war flexibility and mobility are features whose importance cannot be overestimated.

Had the war continued through another year the Shop Section would have grown to be an institution of large

proportions. As it was it accomplished most useful results.

Both the British and French armies maintained tunnelling companies, recruited from among miners, whose duty was the doing of all underground work, such as excavating dugouts with their subsurface chambers and the driving of tunnels to reach points beneath the enemy's positions. The first-named structures will be described in Chapter XXIII. The details of the tunnels presented little of professional interest. They were small drifts only large enough for men to work in and timbered no more than was necessary to support the roof and sides for a short time only. On reaching the desired situation, perhaps beneath an annoying point in the opposing lines of defense, or a controlling one that must be removed before an attack could be launched with hope of success, a transverse gallery or terminal would be excavated. In this chamber a large supply of high explosives would be stored and fired at the critical moment by electricity. What had been a moment before a position bristling with machine guns and crowded with men, would be transformed in a twinkling into a huge crater. The idea was not new, having been used in all wars for very many years. In the past war, however, the introduction of the delicate hearing instruments gave to tunnelling a new aspect and rendered it a more hazardous operation then formerly, one in which success was much more difficult of attainment. As soon as enemy tunnelling operations were discovered to be in progress, it was an easy matter to drive a cut-off gallery and frustrate his attempt. In spite of this the French and British, and unfortunately the Germans also, did succeed in making some very brilliant coups. The American army did but little in this respect. By the time it took a really active part, the character of the warfare had changed from stabilized trench work to open fighting, which presented

little opportunity for operations, such as tunnelling, that required considerable time for execution.

There was one outlet for engineering energy that was just reaching systematic organization when hostilities were ended, the work of salvage. War is inevitably costly and much waste cannot be avoided. The engineers of the allied armies had found that a large part, however, of the waste could be prevented and had established well organized services to that end. They found that nearly every discarded article had some recoverable value. Old clothing could be made over, parts of broken weapons could be assembled, old food cans were worth melting to obtain the solder, while even the refuse of kitchens and lavatories, if only it could be saved, produced grease, out of which glycerine for explosive compounds was obtainable. The grease was collected by ordering the water from all kitchens, bath houses, etc., to be passed through a filter box in which one compartment was filled with straw. The soap and grease were caught in the straw, removed periodically and shipped to places where the glycerine or valuable fats were extracted. To encourage saving among British troops, a percentage of the value of the recovered glycerine was paid to the men of the unit according to the amount and composition of the refuse turned in. The British authorities estimated that the glycerine thus secured cost about £50 per ton as compared with a price in the open market of £250. When the A. E. F. put the saving of refuse into effect, the value of the recovered fats and glycerine amounted to $57,000 in September, 1918, to $109,000 in October and to $120,000 in November.

When the American General Staff realized how great were the possibilities of salvage they began to establish a scientifically organized service. The largest installations were the shops near Tours, where discarded shoes were remade and clothing repaired. The value of the

clothing and shoes overhauled and made wearable at this depot was nearly $20,000,000. In this total were included a great number of the large felt hats with which American soldiers were at first equipped. The hats were subsequently abandoned as an article of issue, because they occupied too much valuable space in vessels, when being sent overseas, and because they could not be worn in the field in connection with gas masks. Instead of discarding the hats, they were cut up at the Tours shops and out of them excellent slippers for hospital wear were made.

There was not a part of a vehicle that was not worth saving and being sent to the Motor Transport Repair Shops at Verneuil for combining to make a new truck or wagon. Even the spokes of broken wheels, fragments of motors and the bent frame of a truck chassis could be and were made use of.

The assortment of articles picked up by the salvage corps was limited in variety only by the number of different things carried or used by a soldier. A list taken at random and given in "America's Munitions" records the following items as the result of one day's business at a single rail-head:

1,100	pairs of leggins	275	German rifles
21	pairs of shoes	3	boxes tent poles
30	leather gun cases	7	boxes gun repairs
21	bags of harness	150	rifle grenade throwers
350	mess kits	4	German machine guns
750	condiment cans	200	German canteens
750	bacon cans	8,000	gas masks
150	first-aid packets	1	ammunition cart
50	saddlebags	4	ration carts
1,400	canteens	17	wagon wheels
200	caps	4	boxes artillery material (telephones, etc.)
900	helmets	1,400	American canteens
1,025	pack carriers		

750	canteen covers	400	American rifles
1	wagon	47	German automatic guns
76	wagon parts	75	gun bolts
50	feed bags	100	respirators
300	pistol holsters		
1	wagon bed		

The total value of articles salvaged in France during the year 1918 was the great sum of nearly $63,000,000, or almost as much as was appropriated for the army during the fiscal year of 1898, which included all of the preliminary expenditures for the Spanish war.

This total was made up as follows:

Value of output, depots and shops.	$47,018,374
Battlefield recoveries	15,100,000
Kitchen economies	474,515
Waste sales	39,680
Rubber.........................	159,157
Wool cloth shipped to the British..	71,984
Lumber.........................	69,025
	$62,932,735

The early efforts in salvage were directed by various and somewhat disconnected authorities, but at the close of the war the whole organization was being brought under the control of the Chief Engineer Officer.

CHAPTER XVIII

MAPS

In no branch of military activity has the complication of modern war been more evident than in the maps of the field of activity and the making of them. No branch, with the possible exception of chemical warfare, has shown a greater development. In 1914 the British staff was entirely without military maps. Even the French relied on maps of their own country plotted on a scale of 1 over 80,000, or about three-fourths of an inch to the mile, picturesque affairs where topography was indicated by hachures, according to the skill or personal taste of the draughtsman. These maps bore original dates of years during the decade beginning with 1830, although marked revised in the years 1910 to 1913. These were the largest scale maps of the theatre of operations obtainable in 1914, except for certain limited districts in fortress areas of which maps were in existence on a scale of 1 over 20,000. The maps of the 1 over 80,000 scale, which were quite sufficient both as to scale and accuracy for the art of war as it existed in August, 1914, formed the basis on which the first battle of the Marne was fought and won.

But the tremendous increase in very long range heavy artillery and the application of the principles of indirect fire to pieces of short as well as long range, together with the development of trench warfare along the entire line of contact, created a demand for maps vastly better in all respects than those existing and to a perfectly appalling amount. To meet this demand it was necessary to plot anew France and Belgium, not only along the battle front but for very extensive areas on both

sides of it — even well behind the enemy lines — on scales varying from 1 over 5,000, where every little detail of topography, including such items as farm buildings, could be shown accurately, to the small scale of 1 over 600,000 where only the main features were displayed.

New plates had to be made frequently in order that new maps might be issued showing changes in the battle line and the constant alterations in and additions to the trench systems.

To do this by the ordinary methods of field surveying was quite impossible within the limits of time available, but aerial photography came to the relief of the mapping engineer through the development of photographic surveying. This surveying brought into play a new art, the reduction of air photographs to map form and accurate scale.

This improvement in aerial photography made it possible to carry on detail mapping in the enemy territory and to plot on maps the greater part of the enemy's trenches, lines of communication, battery positions, buildings and supply "dumps."

The variety of information led to the multiplication of the scale of maps in use, while the complication of modern warfare demanded an increased amount of graphic representation for simplification. In order to derive the greatest benefit from the increased accuracy and scale of the battle maps, it was necessary that the artillery using indirect fire should have a network of triangulation and traverse points on the ground in order to determine the exact location of their batteries.

For the purpose of carrying on this work of surveying, plotting, map-making and printing there were in existence in the various European armies at the time of our entry into the war topographical sections of the various staffs, and in conformity with their practice, there was organized in the American Expeditionary Force in the

summer of 1917, a topographical sub-section of the Intelligence Section of the General Staff, which was charged with the direction and supervision of the engineer troops assigned to this work.

On the military maps of all nations the scale is stated in the form of a representative fraction; thus, the scale of 1 inch to the mile is 1/63360; that is, 1 foot on the map represents 63360 feet on the ground. In France the scale was invariably in some fraction of a thousand and was always spoken of in terms of the thousands that made the denomination of the fraction. Thus a scale of 1 over 20,000 was called a twenty-thousand map. The scales used by the various armies on the western front are shown on the following table:

TYPES AND SCALES OF MILITARY MAPS

AMERICAN	FRENCH	BRITISH	GERMAN
1:5,000*	1:5,000*	1:5,000†	1:2,500 and 1:5,000
1:10,000†	1:10,000†	1:10,000†	1:10,000
1:20,000	1:20,000	1:20,000	1:25,000
1:40,000	1:50,000	1:40,000	
1:80,000	1:80,000	1:100,000	1:100,000
1:200,000	1:200,000	1:250,000	
1:600,000	1:600,000		

* Suppressed by French and Americans, August, 1918.
† Practically discontinued at close of war.

The scales shown in this table for the American army are purely theoretical, since time and means were not available for surveying or redrafting. The American

Expeditionary Force accordingly adopted the French maps and standards. The decision in favor of using French rather than British maps was based largely on the prospective use of French artillery by our troops. The main difference between the French and British maps was in the employment of the metric scale by the former and yard measure by the latter. Before the close of the war the British had decided to change to the metric system, even though this involved re-calibration and standardization of all their artillery range instruments.

In studying this table a surprising feature is the uniformity of practice throughout the various armies, both friendly and enemy. The French 1/80000 and 1/50000 were hachured maps and were, therefore, inferior in appearance, clearness and legibility to all the others which were contoured. The British quickly supplanted these maps by a new 1/40000 contoured map, but prior to the entry of the United States in the war, only sporadic attempts were made locally by individual French armies to produce a 1/50000 contoured map to take the place of their hachured map. The battle areas occupied by American troops were entirely covered at the time of the armistice with 1/50000 contoured maps produced by their own topographical sections, and after the armistice maps of this scale were extended to include the Rhine valley between Cologne and Mayence.

A relatively small amount of original topographical surveying in the theatre of operations was done by the American Expeditionary Force, which took its base maps showing culture and topography from the French. The American maps, therefore, partook of the same characteristics as the French. But the American engineers bore their full share of aerial surveying and plotting of enemy organizations. At the close of hostilities they were keeping their maps up to date and printing all the maps used by troops under American direct

command, which included a number of French divisions.

Comparing the British and French maps, the former were mechanically superior. They were printed on linen-backed or other superior qualities of paper, were more finished in draughtsmanship and workmanship, and much more durable. They were also more accurate in detail for a variety of reasons. The old French maps upon which they were based were in general better and more up to date in that part of the line which the British held. The British, holding the most vulnerable part of the line, were massed more heavily and the area which they were obliged to cover was much smaller. They were thus enabled to do more new surveying and to more thoroughly revise the old work. Another factor which cannot be neglected is characteristic British thoroughness.

The French maps were superior in geodetic control and in projection as is explained below. While the German military maps of Germany itself are very detailed and complete the German maps of the theatre of war were inferior to the allied production both in accuracy and workmanship.

When the battle line became established in 1914, after the first battle of the Marne, and trench warfare followed, there was an immediate demand for large scale maps. Before this demand could be met, there grew up all along the line a series of disconnected sketches and maps made by anyone who was able — or who thought he was able — to survey and draw. These unsystematized efforts frequently produced grave errors in the individual maps, and when an attempt was made to join adjacent maps or sketches, the result was often pathetic. The first step necessary was to cover the entire theatre of operations with a suitable system of triangulation and prepare an accurate map which would use as far as possible the work already done. The scale adopted was

1/20000. The basis for the control was the ancient triangulation of France made in the early part of the 19th century, which located every church spire and natural monument. In the territory occupied by the French this triangulation was in process of revision before the war, and a considerable amount of work had been done. In the territory occupied by the British there had been no revision and the country had been so much fought over by the time that the battle line was stabilized, that a large number of the natural monuments had disappeared.

The question of map projection even for ordinary purposes is extremely complicated from a mathematical point of view. The difficulty arises from the effort to portray the spherical surface of the earth on a flat map. This inevitably leads to distortion and all systems of projection are based on an attempt to distribute these distortions in such a manner that they will be locally negligible. When the average map user attempts to join together a number of maps of a series, covering a considerable area, the difficulty of fitting them together is usually attributed to shrinkage of paper or defects in the maps but is quite commonly due to failure to lay out in advance the system of projection and to join the maps in conformity with this system. For ordinary purposes errors introduced in this way are negligible.

The military map, however, is used for indirect artillery fire commonly at ranges of from three to fifteen miles. It is necessary, therefore, that the exact mathematical location of both the gun and the target be known in order that the range and deflection can be computed. As battery commanders cannot all be geodesists nor even mathematicians, it is necessary that the map be as nearly free from error as possible and that the means of determination of range and deflection be simple or " rule of thumb " methods. Even if the map as originally drawn be free from error, the distortion of the paper

during printing or from the varying humidity of the atmosphere, and the error in joining adjacent maps together render it impossible to determine distances and bearings by measurements on the maps. There is, therefore, superimposed on the map a rectangular grid from which the coördinates of any desired points can be determined and the bearing of the line joining gun and target can be computed from these coördinates. If the grid be laid out in kilometer squares and the range be fifteen kilometers, the constant error due to mechanical map imperfections by using coördinates will be reduced to one-fifteenth of the error from using map measurements, and the errors in laying out lines due to the imperfect joining of maps will be eliminated. The use of a rectangular grid and coördinates also furnishes a ready means of quick determination and description of the location of any point for all branches of the service.

The difficult problem then was to select a method of projection, which, with a single origin for the whole theatre of operations, would not introduce greater distortions at any point than would be allowable for artillery fire and which would permit the superimposition of a rigid rectangular grid with an origin coincident with that of the projection. This problem is mathematically very complex and volumes have been written on the subject. Its exposition within the limits of this chapter is impossible but a brief description will be given of the methods of projection adopted by the various armies and the results obtained.

The British used a projection known as the Bonne system, because at the beginning of stabilized warfare they were in Belgium where maps on a scale of 1/40000 on the Bonne projection existed. When they extended south into France it was natural for them to extend the existing map system, especially since the triangulation of France had been computed and published for the

Bonne system and the conversion into Lambert coördinates involved a long and tedious mathematical process.

The Bonne projection is defined by parallels which are concentric circles and an initial meridian which is a straight line. The spacing of the parallels along the initial meridian is measured by the true latitude arc on this meridian. The subsequent meridians are obtained by laying off on successive parallels the true length of the longitude units, and through the points thus found drawing curves. These curves will intersect at a common point on the initial meridian. It will be seen that distances along the initial meridian and along the parallels remain without error, but in all other directions linear errors increase with the distance from the initial meridian and large angular errors occur for a single fixed origin. These errors might reach values as large as 1/380 in length and 2° 49′ in angular measure for the area involved. In order to reduce these errors to the allowable limit for artillery fire it was necessary for the British to adopt several different origins for the projection and the superimposed grid. Where the map sheets prepared on different origins came together serious difficulties of adjustment arose.

The projection used by the French in preparing their maps was the Lambert, whose essential features are that its meridians are straight lines converging at a common point and that its parallels are concentric circles whose centres are at the point of convergency of the meridians, thus forming a simple conic projection. Distances along the initial parallels have no distortion, but all other distances and angles are slightly distorted. By adjusting the distances between successive parallels a balance may be reached where the angular and linear distortions are the minimum. This adjusted Lambert is known as a conformal projection to distinguish it from a true mathematical projection. For an area not exceed-

ing four degrees of latitude and extending indefinitely in longitude, angular values are correct for all practical purposes and linear distances are correct within 1/2,000.

The Germans used a polyhedral projection over limited areas, were always bothered by failure of their maps to join up at the division line between these various areas, and were consequently compelled to print overlapping maps for each section.

When a single Lambert projection is extended over a wide range of latitude, a conformal adjustment introduces serious distortions. France was, therefore, divided into two Lambert Systems, the Lambert North, between latitudes 50 and 54, and Lambert South which included the territory south of latitude 50. Almost the entire theatre of active operations was included within the area of the Lambert North System.

On this projection was superimposed a rectangular kilometric grid. The origin of the projection and the origin of the grid system were, of course, coincident; the Y ordinate of the grid system being superimposed on the axis of origin of the projection and the X abscisas drawn at right angles to it. The projection being conic and the grid rectangular, north as shown by the grid agreed with true north only at the origin and there was a constantly increasing divergence when moving in either direction from the origin. This had no effect whatever on the use of the map by artillery but for geodetic reasons and comparison with magnetic north the amount of this divergence of the grid north from both true and magnetic north was shown on each map.

This superimposed grid system on the projection divided the battle maps into squares, one lineal kilometer on a side. The lines creating this division were numbered successively from left to right and from the bottom of the sheet to the top. These lines, then, formed the basis for the French system of coördinates.

Through the unremitting labors of the hastily organized French topographical sections, there finally emerged about a year after the opening of the war in 1914, the final French battle map or "Plan Directeur," and since the latter was adopted by the American Expeditionary Force, it will be described in detail. The scale was 1 over 20,000 and the contour interval ten meters, or about thirty-three feet; the culture, including both the natural features and the works of man being printed in black, the contours in brown. Since the map was to be used for over-printing enemy and friendly works and for numerous other over-printings, only these two colors were used for the base. For the same reason care had to be taken not to overload the map with detail. The same consideration governed the use of the rather large contour interval.

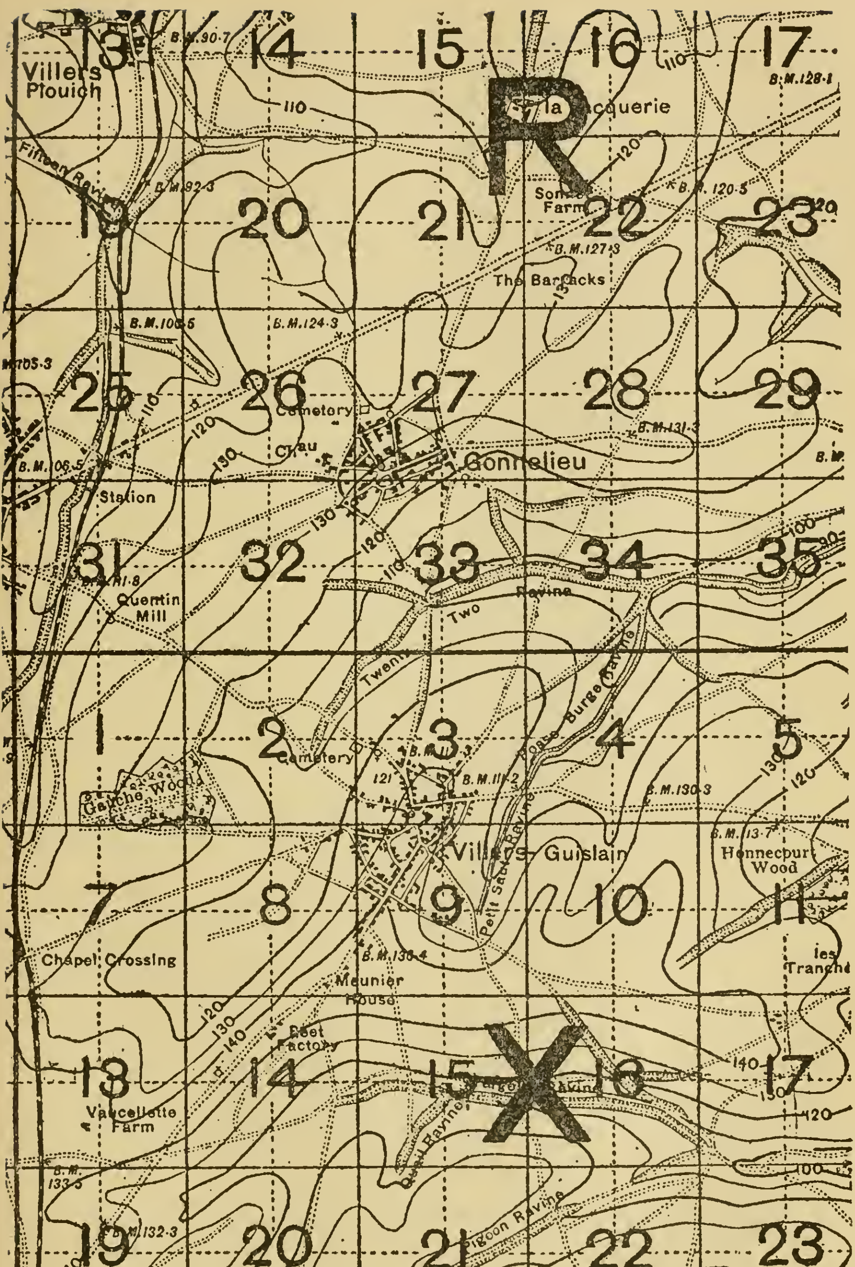
These maps were covered with a rectangular grid of reference lines at intervals of one kilometer, or about six-tenths of a mile in each direction, also printed in black. The origin of the coördinates was at a point in the southwest of France and the coördinates increased to the northeast. As the battle line ran generally in an easterly and westerly direction and was about 500 kilometers long, the maximum east and west coördinate in the neighborhood of Switzerland was +500.

The numerical X and Y coördinates of each grid line were printed on the margin, the unit being one kilometer or 1,000 meters. When locating a point within a kilometer square, coördinates were written out with a decimal point after the kilometer, the X coördinate first as shown on Fig. 4, page 231.

For a location to ten meters this meant writing ten figures, which proved too complicated and cumbersome, so the practice grew up of dropping the first two figures of each coördinate and writing the six figures on one line; the first three representing the X coördinate

and the last three the Y. Naturally, with this method, repetitions could occur every ten kilometers. Both British and German practice avoided these repetitions by using complicated systems of lettering and squares.

The British maps were printed on sheets measuring twenty-six inches high by thirty-five and one-half inches wide, on which the actual map covered nineteen and three-quarter inches by thirty-one and one-quarter inches. As issued they were mounted on cloth and folded to four and one-half inches by six and one-half inches, a very convenient size for the pocket. The main grid system divided the surface into squares 6,000 yards per side, each one being given a lettered designation, and as there were twenty-four large squares to a sheet, these letters ranged from A to X inclusive. The large squares were divided into secondary squares measuring 1,000 yards per side and numbered 1 to 30, a separate series for each letter and each secondary square subdivided into four smaller squares lettered, a, b, c, d. The map, p. 227, is a photo reproduction, exact size of a part of a British 1/40000 map. The large or primary squares with their designating letters are shown, as well as the numbered secondary squares, and the subdivision of the latter into small squares indicated by the dotted lines. The method of portraying the features of the topography and the contours are clearly seen, although colors are lacking in the plate. To show how the system of coördinates was used to describe the location of a point, Vaucellette Farm can be taken as an example. This would be written 57CX13c8.5, where 57C is the number of the map, X the primary square, 13 the secondary square, c the lower left-hand quarter of the secondary square, and 8.5 the horizontal and vertical coördinates in the square c, measured from its lower left-hand corner as an origin of local coördinates. As these small squares measured 250 yards to a side, each decimal unit in the coördinates



For Description See Page 226.

represented a distance of only twenty-five yards. By using larger scale maps and writing these coördinates in two or even three places of decimals, a very high degree of accuracy in writing the location of points on a map was obtained.

Finally, toward the close of the war, all allied nations combined in a modification of the French system. Every fifty-kilometer square was divided into twenty-five ten-kilometer squares, each of which was given a separate letter of the alphabet. Enlargements of a ten-kilometer square and of a kilometer square are shown in Figs. 2 and 3, and the method of designating a point is described under Fig. 3. At the close of hostilities both French and Americans had effected the change. When we consider the incessant use of the military map to give exact locations, and the constant repetition of these locations in documents by the artillery and infantry over the wireless, telephone and telegraph, the importance of this simplification and improvement cannot be overestimated. This change, together with many others looking toward the simplification and standardization of allied practice, was effected at one of the meetings of the Inter-Allied Map conferences, which were instituted as a result of America's entry into the war.

The map on page 227 has particular local interest. It gives a part of the battlefield of Cambrai, that city being just beyond the upper right corner, the British offensive in that battle beginning just east of Villers-Guislain, extending thence north and west past Gonnelieu and through Villers-Plouich. Here it was that the Germans made their counter offensive, and at the point marked "Station" in square R31, the Eleventh Engineers made their stand, described officially as the first American participation in actual fighting. The village just on the edge of the map west of R31 is Gouzeaucourt. The size of the sheet was exceedingly convenient to

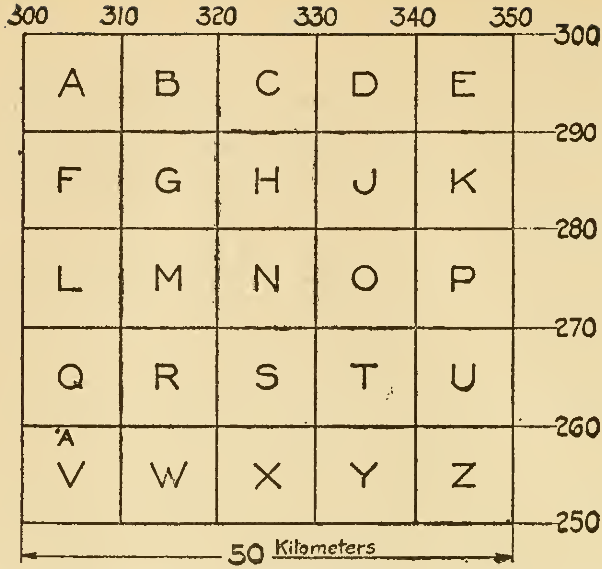


Fig. 1.—Inter-Allied System. Method of Lettering Fifty Kilometer Squares.

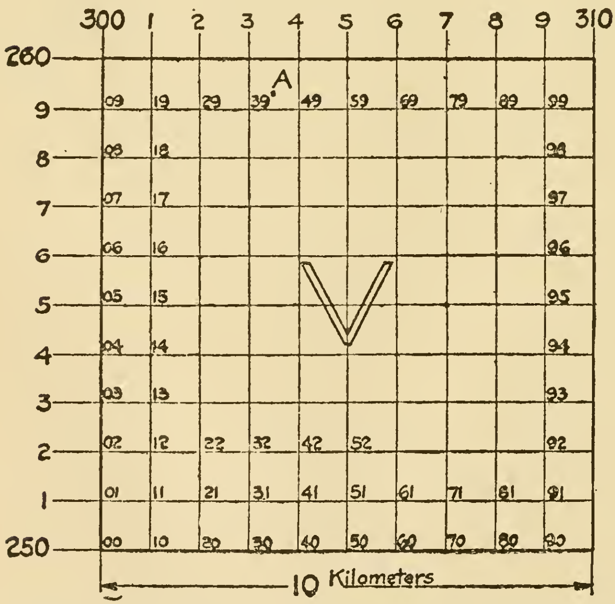


Fig. 2.—Inter-Allied System. Ten Kilometer Square Enlarged—Method of Numbering Kilometer Squares.

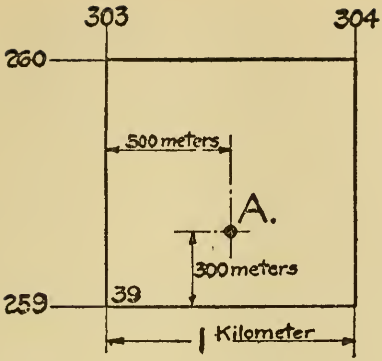


Fig. 3.— Inter-Allied System. Kilometer square enlarged. Point "A" is the same as shown on Figs. 1 and 2. Coördinates of Point "A" within Square V are Written V3593, a Point 20 Meters N. and E. of Point "A" would be V352932. A Point with Similar Figures May Occur Every 50 Kilometers.

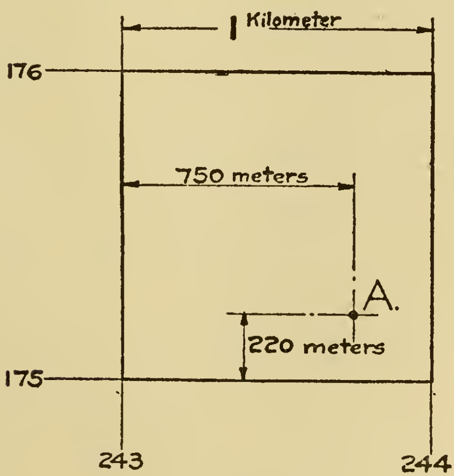


Fig. 4.— Old French System. Kilometer Square. Coördinates of Point "A" Written as Follows, in Full: 243.75—175.22, or Abbreviated: 375.522.

handle, and the form was better than the American in that the major dimension was right to left, which conformed to the shape of desk tops and was easier to hold in the hands than one where the major dimension was from top to bottom.

The base map thus prepared formed a foundation for the over-printing of military information. The Battle Map, or "Plan Directeur," normally had over-printed on it the enemy's trenches and defensive organizations and the location of the enemy's batteries and means of communication. In this form it was issued to troops down to units as small as companies.

Hostile trench systems were over-printed in blue and friendly trenches in red on the French maps. The Germans reversed this procedure so that a captured German map could be interpreted by the French in the same way as one of their own maps. The British color system was the same as the German, that is, allied trenches in blue, enemy in red.

The Battle Map again formed a base for the preparation of special maps, of which the most important was the Artillery Bombardment Objective map, which accentuated by over-printing in different colors the points upon which fire should be concentrated so that the maximum result could be obtained from the minimum expenditure of ammunition.

Next in importance was the "Enemy First-Line Positions," a detailed study for the infantry, portraying the important objectives in the enemy's defensive organization and the manner in which they were held, the important trenches being accentuated.

Similar special maps were prepared for other offensive branches, such as the air service and tanks. Secret maps of our own trenches shown in red, and lines of communication were made for our own construction and supply services.

The size of the American sheets was generally twenty-eight and one-half inches by forty-two inches, the major dimension being from top to bottom.

To insure the most efficient use by the artillery of the Battle Map and Artillery Bombardment Objective Map, it was necessary to lay out on the ground for each battery or group of batteries traverse and triangulation points, from which their exact location and direction to the various objectives could be determined.

In describing the organization of the American topographical section, it is necessary to explain briefly the growth of the European topographical sections prior to our entry into the war and their organization as found by the American Expeditionary Force on the arrival of its first units in France.

The French topographical organization was formed by a combination of the mobilized "Service Geographique de l'Armée" and the "Groupes de Canevas de Tir," which latter may be freely translated as Fire Control Sections. The "Service Geographique," operating in time of peace under the direction of the Minister of War, is the organization which would exist in this country if the Coast and Geodetic, Geological, Hydrographic and Land Surveys were combined into one bureau under the War Department. At the outbreak of the war the "Service Geographique" was strong in personnel and matériel. The "Groupes de Canevas de Tir" were organized originally by the artillery and were controlled by that arm until taken over by the "Service Geographique." After that the "Service Geographique" exercised technical supervision over their work and furnished them men and materials. However, in the armies and lower units they came at first under the control of the Second Bureau or Intelligence Sections of the respective staffs, and finally, rising to be a separate branch of the staff, reporting directly to the Chiefs of Staff of the respective units.

In the British army the place of the "Service Geographique" was taken by the "Ordnance Survey," operating under the control of the map section of the general staff. The units in the field were field survey companies working as part of a map subdivision of the intelligence sections of their respective staffs, officially known throughout the British Expeditionary Force as "Maps." Due to its work in the British colonial empire, the Ordnance Survey at the outbreak of the war was rich in experienced personnel. Like the American topographical division, the entire personnel of the British service, including the staff officers, was drawn from the engineers. In both the British and French armies, the Sound and Flash Ranging services, which had grown to large porportions, were under the control of the topographical divisions.

The German system was somewhat similar in organization and staff control, except that the sound and flash ranging and a considerable part of the topographical duties which pertain directly to the control of artillery fire remained under the artillery, as was formerly the case with the French.

It was necessary for the American Expeditionary Force to create not only topographical sections for its armies, but also to maintain in France a service similar to the British Ordnance Survey and French Service Geographique.

Prior to our entry into the war, map making had been a duty of the Corps of Engineers, but for the American Expeditionary Force, staff control was adopted in conformity with European practice. Had it been a question of original topographical surveys alone, the work might have remained under engineer direction, but due to the development of airplane photography, most of the maps included information regarding the enemy, which had been collected by the intelligence section of the Gen-

eral Staff. The topographical work was accordingly organized with engineer personnel under the topographical division of the Second or Intelligence Section, General Staff, commonly abbreviated to G-2-C. At general headquarters in each army, corps and division, there was a staff officer (assigned from the engineers) in the G-2 or intelligence section, who exercised supervision and technical control of the work of the following troops:

G. H. Q.— One battalion of three companies (topographical) 29th Engineers, operating the base printing plant which corresponded to the Service Geographique and Ordnance Survey, and also furnishing a topographical section to the general staff at General Headquarters.

For each army:— One battalion of three companies (topographical) 29th Engineers, corresponding to the " Groupes de Canevas de Tir " and " Field Survey Companies."

For Divisions and Corps:— Detachments from the Army Topographical battalions.

At the time of the Armistice there were two armies in the field and the authorized strength of the attached topographical troops was nominally nine companies. Of these only five were on hand, of which three had been organized in the American Expeditionary Force from engineer replacements. This lack of personnel was largely compensated by the zeal and efficiency of the enlisted men, who set a pace that although it lasted over the emergency, could not have been sustained indefinitely.

The detailed duties of the topographical organization formed from the Twenty-ninth Engineers were as follows:

Surveying.
Restitution of aerial photographs.

Map making.
Map printing.
Map distribution.
Special maps and plans for staff branches.
Triangulation and traverse control of artillery fire.
Relief map making.
Panoramic photography and visibility studies.
Photographic reproduction.
Type printing, including publications, pamphlets and propaganda.
Engraving.
Adopting standards and furnishing technical advice and supervision.

In conformity with French and British practice and because it could be more easily organized and developed by engineer personnel, the Sound and Flash Ranging Service, which is more properly a duty of the artillery, was also placed under the control of the Topographical Division, but its work will be described in another chapter.

Another important aid to the artillery, which in time of active operations occupied about one-third of the personnel of the army topographical sections, was the means afforded by which the batteries could locate their positions on the map and thus compute the bearing and distance to invisible targets. The coördinates of all prominent natural objects were either obtained from old records or determined by triangulation and were issued in the form of tables, with silhouette sketches for purposes of identification, to all battery commanders. Any artilleryman within view of three points could locate his battery by tri-secting with a plane table. This was sufficient for rough work in open warfare, but when the battle line was stabilized, traverses tied into the triangulation system were run through all actual or prospective artillery positions. These traverses were marked with

special stakes and the coördinates of each station and the bearings of the lines connecting them were issued in the form of tables. These traverses, called by the French "Canevas de Tir" or "network of fire," enabled very large concentrations of artillery to be directed with accuracy on invisible targets without any preliminary registration. This survey work was all done by detachments of the Twenty-ninth Engineers from the army topographical battalions.

When the first units of the American Expeditionary Force arrived in France, in July, 1917, the Topographical Service consisted of but one officer and eight men, operating a hand lithographic press. The first and most urgent undertaking of procuring and distributing maps was immediately begun, the sources of supply being the French and British topographical services. The next step was the construction and the accumulation of the mechanical equipment for a base printing plant, corresponding to that of the Service Geographique, and for smaller plants for armies, corps and divisions. All of the equipment and supplies were furnished by the Engineer Corps in the early stages through purchase in Europe, and, toward the end, largely by shipment from the United States. The base printing plant was placed in operation in July, 1918. After September 1st, the American E. F. was independent of outside aid for its supply of maps. The First Army plant began to work in August, that of the Second Army in October, and of the Third in November. Meanwhile, plant, equipment and personnel had been furnished to each corps as organized, the total number of corps having reached nine in November, 1918. These plants turned out more than 15,000,000 impressions and printed about 4,500,000 of the 6,000,000 maps distributed to the American Expeditionary Force.

While the mechanical problems connected with install-

ing, equipping and operating the plant were successfully solved, the technical problems of procuring information and the reduction of this information to the most satisfactory form for presentation, although also successfully met, were much more difficult of accomplishment. This was due partly to the inherent difficulties, but largely to the lack at the outset of trained personnel and the entire newness of so many details of military map making, that had arisen as creations of the war. Of the 1,800 officers and men in the topographical service at the conclusion of hostilities, about one-half were employed in the reproduction plants, on work that differed only in detail from their regular vocations before their entrance into the army. The other half, scattered throughout the field forces, were called on to practice arts which were either unknown or little used before the war. The most important of these were: interpretation of aerial photographs and their restitution or reduction to map form and scale; the preparation of initial copies of countless special and periodical maps for Intelligence operations, artillery, and other branches, a work which required comprehensive military knowledge; the perfection of the organization for gathering the necessary information and for editing and publishing it in intelligible form and on a time schedule, and the establishment of the necessary liaisons with troops and with staff corps for this purpose; traverse and triangulation surveys for the control of artillery fire and publication of the results, which required special knowledge of the principles of artillery orientation; the preparation of relief maps; and the making of visibility studies. The personnel for all of this work were trained at the topographical schools especially established at Langres in the autumn of 1917, using French and British documents and photographs with American instructors who had been instructed in French and British schools.

Beginning with the Château-Thierry operations in June, 1918, graduates of this school were furnished to the topographical sections of corps and armies, and American data began to be used in the school. Actual surveys made after the conclusion of the Armistice showed a gratifying degree of accuracy in the study and mapping of enemy organization.

Not only was the American army independent by means of its own special force in the making and supplying of military maps at the close of the war, but it had outstripped the other allied services in two highly important respects: speed and mobility.

Speed, so essential in all military operations, was imperative in the publication of maps and other intelligence information. In war, information a day late is often useless. Greater speed was secured through the superiority of American machinery and through the characteristic desire of Americans to use only the latest improvements in plant and methods.

Mobility was secured by mounting specially designed lithographic presses and auxiliary apparatus on motor trucks, so that they were enabled to accompany armies and corps throughout their movements and to begin to operate within two hours after arrival at any place.

The paralysis resulting from the lack of such mobility was illustrated during the German offensives in the spring of 1918, when three allied army reproduction plants were put out of action for periods of three or four weeks with the same serious effects as the stoppage of the daily newspaper would have on modern civilization. During the advance to the Rhine, the British and French armies were accompanied by mobile lithographic trains loaned by the American army and operated by American crews. The work done by these trains was the only reproduction work which these armies had for nearly a month.

Before proceeding with a further detailed description of the base printing plant and mobile trains, it would be well to outline the division of work between the base plant and the armies. The surveying, drafting and printing of base maps, and the making of relief maps, was done by the base troops. The interpretation and study of aerial photographs, their restitution and the overprinting of enemy organizations on base maps to make a battle map, and the establishment of artillery firing data were the functions of armies and were performed by the army topographical battalion. In one American army at the close of hostilities thirty-three periodic maps were being produced, the time of publication ranging from daily to monthly and the editions from fifty to 4,000 copies. In times of great emergency, such as during the St. Mihiel and Meuse-Argonne offensives, when it was necessary to revise and republish in large quantities every map in the army, the base printing plant came to the army's assistance, printing nearly 1,000,000 copies for these two operations alone.

The base printing plant employed about 800 men, divided into two twelve-hour shifts, and occupied about 60,000 square feet of floor space. It included thirty-eight lithographic presses, eighteen type presses, six linotype machines, stereotype, photo-engraving and zinc-etching appliances, wet and dry-plate photography transferring process rooms, power plant, machine shop and the necessary auxiliary machinery. While not so large as similar plants of the Allies, it was completely equipped and especially designed for the production of a large bulk of work at great speed. The army plants were much the same in principle though on a smaller scale. The mobile army printing train, which was not completely assembled and in operation until after the Armistice, consisted of thirty-nine motor trucks ranging from 1,500 pounds to five tons capacity and contained the most modern

equipment for lithography and map printing, type printing and stereotyping and wet and dry-plate photography, zinc etching and photo engraving. Each train was independent in supply, power and repair facilities, and contained its own telephone exchange and wireless apparatus.

There was no opportunity to try out this train in actual warfare, but its component parts had all been in service with various corps and armies during hostilities. Nevertheless, to demonstrate its practicability, it was operated in the field for one month under simulated war conditions, and proved a complete success. That its value was appreciated is demonstrated by the fact that the French government placed in the United States an order for ten lithographic trucks to form a nucleus for similar trains for their armies.

General Pershing stated in an official communication that no army ever started an offensive operation better provided with intelligence, information and maps than the First American Army in the St. Mihiel offensive. This was due to the work of the Twenty-ninth Engineers, who, in addition to printing and publishing the great mass of intelligence documents that were used, also furnished 327,000 copies of maps prepared from data furnished or collected by them. The initial issue of fifteen tons of these maps was prepared in less than two weeks and was so timed as to permit distribution to the numerous units which moved to the front from all portions of the American area at the last moment in great secrecy. The high standard set in this achievement was maintained, and even exceeded in some respects, in the more difficult Meuse-Argonne offensive.

The striking feature of this operation was the great independence and efficiency developed by the corps printing trains which were operated by the detachments of the Twenty-ninth Engineers. In the war of movement

and the consequent interruption of communications which developed in this operation, time was not available for preparing up-to-date battle maps in the army topographical section and base printing plant. Mobile printing trains, however, made it possible to print maps in quantities and with great speed at the front, and the value of this work to our combatant troops was immeasurable.

After the Armistice there was little diminution in the work of the Twenty-ninth Engineers until their departure for the United States, in June, 1919. In addition to the organizaion and equipment of the Third Army Topographical Section for the Army of Occupation, intensive work was carried on in the preparation of maps of the occupied territory and of other parts of Germany beyond the Rhine, that the army might be prepared for the possibility of a further advance. In addition to the army and battle maps, great numbers of maps were produced to accompany historical and technical reports of various department chiefs of the American Expeditionary Force.

The volume of work accomplished is shown in the following tables:

LITHOGRAPHIC MAPS

SCALE	NUMBER OF COPIES	NUMBER OF IMPRESSIONS
5,000	12,050	22,100
10,000	184,420	450,720
20,000	1,016,825	2,361,300
50,000	498,385	864,825
800,000	569,975	596,250
200,000	494,075	2,164,560
Special	458,608	875,530
MAP TOTAL	3,234,330	7,335,285
Miscellaneous Lithographic Work	1,371,200	1,961,440
	4,605,530	9,296,725

ALL GRAPHIC REPRODUCTION WORK

	ORDERS	IMPRESSIONS
Lithographic Map Department	2,275	9,296,725
Type Printing Department	855	5,865,953
Photographic Department	1,197	23,791
Photographic Engraving Department	174	1,622
TOTALS	4,497	15,208,091

When it is realized that two-thirds of this work was done in the five months from August to December, 1918, this represents an enviable record of achievement. It must be remembered, however, that less than half the men attached to the topographical section were engaged in reproduction. The work of the others, whether in running artillery traverses or taking photographs under fire, or in the delicate arts of interpretation and restitution, cannot be measured by statistics.

CHAPTER XIX

FLASH AND SOUND RANGING AND SEARCHLIGHT DETECTION

If the target was unseen by and perhaps unknown to the gunners, through the use of indirect fire controlled from a distant observation point, so were the guns themselves equally invisible from the target. But if an effective reply to a harassing fire were to be made, the position of the guns must somehow be accurately determined, even in spite of this invisibility.

In former years when the range of guns did not exceed a mile or at most two, and guns were individually aimed over open sights, they were in full view, or if sheltered, their location would be disclosed by the pall of smoke. With guns of much longer range and no telltale smoke, special means of discovery had to be devised. This gave rise to a most interesting game of hide and seek, where both sides resorted to every strategy of concealment and means of discovery. One form of misleading disguise was to create false positions. To make guns unrecognizable, ingenious forms of concealment were adopted, taking suggestions from the coloring of the wild animals, which affords them protection by making them indistinct through their resemblance to surrounding earth or foliage.

To tear off the hiding veil, to see the unseeable, to learn of the unknown, recourse was had, since the human eye was useless and the ear unreliable, to many beautiful applications of optics and acoustics, employing electromechanical instruments almost uncanny in their accuracy. Among these instruments were the microphone which transforms the vibrations of sound into fluctua-

tions of electric current, the geophone which multiplies the intensity of sound travelling through the ground to many times its original volume, and the amplifier which magnifies the effect of an electrical wave. These instruments with a delicacy of make hitherto considered practicable only for laboratory work, permitted men to see through darkness or over hills, to separate sounds as a game dog will distinguish between the scent of different birds, and to be able to hear actually down into the very earth itself.

Sight is, of course, man's best sense for determining distant objects, and the airplane gave him not only increased range but a wholly new point of observation. Hills were no longer obstacles to sight. In his flying machine he could surmount them, and inspect at will and in detail the country beyond. Batteries, unless covered, could be detected with ease and certainty. At the beginning of the war, owing to the limited range of guns for vertical fire, observation airplanes could fly safely, so far as attack from the ground was concerned, at an altitude of 5,000 feet. At such a height the human eye can satisfactorily determine the character of objects on the ground. But the designers of anti-aircraft guns were active, and "Archies," the special anti-aircraft guns, greater caliber, longer range, and of greater precision were being turned out. With each step in progress the airplanes were obliged to keep at constantly increasing altitudes until finally no height was safe against surface guns less than 15,000 feet, or say three miles. Why anti-aircraft guns were called "Archies," except that it was a contraction of Archibald, could never be learned. Who Archibald was, and why his name was made so memorable, no one seemed to know.

At a height of 15,000 feet or anything approaching it, in a vibrating machine travelling at 100 miles per hour, the eye ceases to be sufficiently accurate and the more

sensitive instantaneous photographic lens and film were pressed into service. As the "Archies" were improved, forcing the planes to fly higher and higher, so likewise was the photographic apparatus developed, bringing the earth in effect nearer and nearer, until even at a height of 15,000 feet, pictures were obtained showing with vivid clearness all the objects on the surface.

But those in defense were not beaten, and art and trickery were called to aid. Guns were covered with all sorts of disguising protection. The barrels and limbers were painted with various colors, rivalling in gaudiness the leopard or the zebra, and when not in action they were covered with screens of boughs or nets in which were entwined pieces of canvas imitating leaves or earth. As the photograph would be taken vertically, it was not so much the outline of the object that would be shown but the shadow, and it was, therefore, desirable that the form of the gun should be broken by contrasting colors and that a sharply marked shadow should not be cast.

The success attained by the camouflage expert in disguising or completely hiding guns was really remarkable. Guns actually in action could not at times be discovered at a distance of a few hundred yards unless the flash was noticed at the instant of discharge.

Faked positions were frequent so that on a given hill slope, where it was known that batteries were posted, it was difficult to distinguish the real from the imitation. In fact, were it not for other telltale marks it would have been impossible to locate batteries by direct observation.

These marks were the momentary flash of the gun, either direct or reflected, the permanent effect of the blast and the evidences of human work and occupancy. The last were indicated with marked distinctness on the air-photos by dugouts and kitchens, by the paths worn by the feet when walking from them to the guns and by the roads worn by wagons in bringing up supplies and

ammunition. The increasing definiteness of these telltale signs in pictures taken on successive dates, was sufficient to lead to the detection of the battery. This difficulty was partially solved by establishing batteries alongside roads.

The effect of the blast of the guns was a sure sign, and one very difficult to conceal. The rush of air following the discharge killed all verdure in its path, making a dark stain, whose unmistakable character would be recognized on the photographic plate. Even bare ground would be affected by the blast. Ordinarily the shelter afforded by trees would offer splendid concealment, but here the killing blast would at once leave its record. There was once a German battery that caused much annoyance, but so carefully had it been hidden from vertical observation that its position could not be discovered. It had been stationed on the shore of a small lake and the water surface gave no sign of the blast from the guns that passed harmlessly over it. With the coming of winter the pond froze. The next photograph showed the effect of the blast and the destruction of the disturbing battery promptly followed.

This photographic work was not the simple matter that the above few words might seem to indicate. We have all had experience with ordinary photography and know how details are lost when the object is but a short distance away for, though a pretty picture results, the landscape is shown in broad shadows or contrasting lights without detail. Such a picture, however attractive from an artistic point of view, will not answer military requirements. The latter demand that prints show accurately the minutiae in the field, exactly as a distant view appears when examined through a powerful telescope. In photography this is accomplished by using special lenses set in peculiar cameras giving a telescopic effect, that is, limited breadth but magnified detail. But with

photographs taken vertically, a new difficulty was found in the haze caused by the moisture in the atmosphere not present close to the ground, a difficulty finally overcome by using screens or color filters permitting the far-reaching lenses to pierce the inconvenient haze. The cameras attached to the very swiftly moving airplanes were subject to their jarring vibrations. To prevent the latter from completely spoiling the picture, the shutter must work with great rapidity, but such short exposures will not give great distant detail except on especially prepared plates. Apparatus of a character that would overcome all the above disturbing effects did not exist before the war began and had to be developed step by step, calling for highly scientific and resourceful research work on the part of skillful opticians and chemical engineers. But all the difficulties were not yet conquered. The cameras had to be so attached that they could be sighted and worked by the aviator with the minimum of effort on his part so as to allow him to devote his attention to his engrossing duty of handling his machine, and dodging shells from enemy Archies or machine gun bullets fired from a hostile plane.

The French cameras took negatives on glass 18 cm. by 24 cm. (approximately 7.2 in. by 9.2 in.), while the British used 4 in. by 5 in. plates. The latter were usually enlarged for examination while prints from the former were made direct. The most satisfactory lens was one with a focal length of about twenty inches. Of such apparatus the United States possessed none in 1917, being obliged to develop even the manufacture of the optical glass of which Germany had previously supplied the greater part. There was finally evolved a very satisfactory camera of American design and manufacture, using films instead of glass, but of the French dimensions, 18 cm. by 23 cm. As an indication of the demand for photographic supplies, there were shipped to France during the month of Octo-

ber, 1918, among other items, 1,500,000 sheets of paper, 300,000 dry plates, 20,000 rolls of films and twenty tons of chemicals.

After a picture was taken, developed and printed, no little skill was required to discover and correctly read its message. To the untrained eye there would appear nothing but empty fields and barren roads, while the expert would see, especially after comparing the picture with previous ones of the same locality, results of shell fire, new batteries, recent construction carefully concealed, or other signs of troop movements.

Great as was the progress of aerial photography and the perfection of the apparatus, batteries could not always be located with certainty by such means, and recourse was had to other applications of scientific methods.

An accurate means of locating a distant gun is by its flash. If a gun were so placed that it could be seen from two points, two observers using ordinary surveyors' transits could obtain the relative bearings of the spot of light. Then with the distance between the observers being measured, the determination of the location of the flash on a map was a matter of simple triangulation computation. There was one serious chance for error to be guarded against in this otherwise exceedingly simple method and that was that the observers might not be registering on the same flash. To be certain of this and to eliminate all readings that were not on the same gun, each observer, usually there were several, at the instant of noting and recording a gun flash, would push a button on an electric wire and actuate a small light in the central station, perhaps some miles away. Then each one would immediately telephone to the same office his reading of the bearing of the flash. If the lights from three or more of the observers showed simultaneously and the bearings intersected at a point, it could be

assumed with absolute assurance that they were registering the same gun.

Flash ranging was effective in locating a very considerable part of the field artillery posted within two or three miles of the front line, but was relatively ineffective in locating the hostile heavy artillery, which was usually so far back that even the reflected flashes were screened from direct observation. In the event that guns could not be observed by direct vision, then recourse to airplane observation was necessary. But if the eye of man, even when aided by telescopes and the highly sensitive photographic plates, was the sole means of detecting enemy's guns, many, perhaps the majority, would have escaped the most vigilant observer, on account of the difficulty in making accurate aerial determinations for the reasons given above or through the skill of camoufleurs. Undiscovered the guns could continue to inflict damage with impunity. Flash ranging and airplane observation both required clear weather, but during six months the climatic conditions in northern France are unfavorable for observation.

When direct vision and photography failed to give results the engineer called acoustics to his aid. Light travels in straight lines and if a hill intervenes between the enemy battery and the target or observer, the flash cannot be seen. But exactly as the projectile in its flight makes a curved path from gun to destination, the sound of the discharge passes over the obstruction. If the flash cannot be seen the discharge can be heard. This physical fact opened a new field for scientific observation.

Another characteristic of the sound wave in which it differs from that of light is in its vastly slower rate of travel, being under normal atmospheric conditions and at a temperature of thirty-two degrees Fahrenheit (zero centigrade), 1,086 feet per second, as compared with 185,000 miles per second for light. This velocity of

sound is easily measured and, if the exact length of time taken by the passage of sound between the point of origin and the hearer is known, the distance travelled can be computed within a negligible error. Now if instead of one hearer there be several who catch the sound of the discharge of the gun, for instance, at different moments of time and if the exact instant when the sound reaches the several observers can be separately measured in seconds and fractions of seconds, the difference in distance between the gun and each observer can be computed on the basis of 1,086 feet per second. As these differences determine the direction from which the sound comes as well as its distance, it is the work of only a few minutes and a very simple calculation to ascertain the position of the gun provided the relative position of each observer, with respect to the others, is correctly indicated on a map. In fact, with the observing points plotted on an accurate map, the determination is made mechanically by the intersection of adjustable strings.

The figure of velocity of 1,086 feet per second is subject to small corrections due to temperature, atmospheric humidity, wind, etc., which are readily made. This correction was determined on the British front by firing a gun, whose position was definitely known with respect to all observers, at frequent regular intervals. The instruments would record the differences in arrival time of this signal sound and the variation from a standard time interval would give the combined correction for all atmospheric conditions as they actually existed at that instant. The American method was to report the meteorological conditions as determined by observation balloons. Had the war continued, some better system would have been installed.

The human ear is quite incapable of measuring small fractions of seconds. Even if it could, man could not record the sensation with sufficient accuracy, so the engi-

neer was obliged to devise a machine that could both hear and record the gun reports with absolute faithfulness and accuracy. Without absolute accuracy it is obvious that it would have been impossible to locate enemy guns, and accuracy means in this case a permissible error not exceeding one-twentieth of a second.

Such a machine was actually devised and used with great success. To describe in detail this beautiful instrument with its delicate sensitiveness, and unfailing accuracy with parts so rugged as to be capable of withstanding long exposure to wet, storm, cold, heat, and to continue working entirely automatically under the rude conditions of battle, is beyond the scope of such a book as this. But the solution of the problem by the French, the British and the American physicists stands as one of the great scientific achievements of the war, and is remarkable as being one of the few steps in the application of science to war wherein the Allies distinctly excelled the Germans.

In general, the apparatus as a whole consisted of a series of detectors or sound catchers, each detector constituting, therefore, a separate observing station, and all the detectors being connected with an automatic recording instrument by means of wires carrying a low electric current. The delicate hearing device or artificial ear was a piece of platinum cloth, heated by an electric current. The cloth was so sensitive that its temperature would be lowered by the small air waves which would be set in motion by the vibrations due to sound impinging on it. The electrical resistance of the wire cloth varied with changes in temperature. By thus affecting the intensity of the current flowing steadily through it the current gave a means of communicating to a distant point not sound, but the disturbances that indicated sound, and this same variation in current operated the string of a string galvanometer.

The field detector part consisted of a drum in whose diaphragm was fixed the electrically charged platinum grille or cloth. These detectors, usually six to a group, were carefully screened against shell fire and wind. They were scattered over several miles of front, depending on local conditions, but the location of each detector was accurately known and plotted on a map. The recording instrument with which the detectors were connected was set up in the rear in any convenient dugout or building where it would be reasonably safe from hostile fire.

This central instrument had a strip of sensitized films on which were photographed by a moving picture camera the strings of the galvanometer, each string being electrically connected with one of the detectors. If the electric current was of constant intensity, the strings were undisturbed and gave straight-line impressions on the sensitized strip as it was unwound mechanically from a reel. Whenever the detector diaphragms were affected by a sound vibration, the current was momentarily interrupted and the string made a small jump at right angles to the strip, breaking its straight-line trace. Immediately afterwards the string resumed its original stationary position and was ready for another gun. By photographing on the same strip the strings corresponding to all the stations, together with a time scale, the actual difference in time that a sound took to reach the several detector stations could be recorded and measured.

The sensitized tape was given a perfectly regular motion and at such a speed that intervals of one hundredth of a second could be measured with accuracy.

Since sound travels at the rate of 1,086 feet per second, the error in an instrument reading to hundredths of a second becomes negligible. Errors in surveys, mapping and atmospheric corrections, however, affect results to such an extent that sound rangers claim no greater accuracy of location on a single reading than

within fifty yards. This is not only within the variation in accuracy of a gun firing at an unseen target some miles away, but is well within the deadly effect of shell fragments following the burst of a shell directed at the gun in question. A battery whose position is known within such a maximum error in distance can soon be destroyed.

Accuracy of determination was rated on three scales, P, Q and R. A "P" location was one where four cords intersected on a map, when it was safe to assume that the error did not exceed fifty yards. When only three cords intersected on the map it was a "Q" determination and the limit of error was assumed to be 100 yards, while two cords gave an "R" indication with an assumed error of 200 yards. Repeated observations which agreed with each other gave a more reliable basis for assumption than even a single "P" determination.

Skill in accurately picking out and reading the messages on the films was quickly attained, and finally to a trained observer the characteristic impression of the sound, of each different type of enemy gun became as familiar as the faces of old friends. This method of locating guns could be carried on at all hours of the day or night and could be interrupted only by the frequency of sound reaching the proportions of a barrage. The same instrument could also be used to direct the fire of friendly guns on located enemy positions, when the instruments would be concentrated on locating the sound of the bursts of the outgoing shells and correcting the aim to the point at which the enemy gun had been located.

From these instruments the best means of escape was either through a confusion of sounds by firing several guns simultaneously, by frequent changes in battery position, or by registering on a target with one gun and leaving the battery that was to do the execution silent

until the moment for action arrived. Such attempts at evasion were highly unsatisfactory, and the fact remained that the very beautiful sound-ranging outfits of the Allies had the German gunners at a very serious disadvantage.

Both the French and British experts produced sound-ranging apparatus of highly satisfactory type which, while differing in details, were founded on the same scientific theory. When America entered the war the army had no such outfit because it was not only a most recent product of the war, but even at that date was still in course of initial development. The Engineer Department selected the British machines as being more reliabe and portable than those of the French, and while supplying our own troops with such instruments, began the development of an improved form, which promised to be the superior of its prototypes in cost and ease of handling, and to be less adversely sensitive to annoying conditions. But the conclusions of hostilities deprived this device of a field trial.

The microphone detectors were placed far forward in order to receive as great a sound impulse as possible, and if not actually in the front trenches, were set up but a short distance away. The connecting wires, therefore, ran back across the open country subject at any or all times to bombardment. Since they must be repaired the moment a break is discovered, engineers for this purpose lived in forward dugouts whence they could be called quickly by telephone. Under such conditions maintenance was not the easiest labor, nor was it particularly pleasant to be called out of a bunk on a cold and stormy night with an order to find and repair at once a break in a line, with no certain knowledge where the break or breaks were, for there might be more than one. Lights could not be carried for fear of attracting hostile fire. Perhaps the only way to find the cut would be to take

the wire in hand and so follow its trail, tumbling into shell craters half full of water, climbing in and out of disused trenches, or stumbling over some object unseen in the darkness, and hearing every few minutes the s-w-i-s-h of a shell overhead or the still more unpleasant loud c-r-r-u-m-p! as one burst nearby scattering splinters and sodden earth in all directions.

The several lines of signal wire were usually named so that the message describing a break would take some such form as "Bennie is dead." One night a new recruit was at the phone board and when the above message came in, he, not knowing the code, answered, "I am so sorry, was he one of the boys at Central?"

Besides locating the guns it was also necessary to find and render visible enemy bombing planes at night. The German motors had a distinctive note and could be recognized easily, provided they were low enough to be heard as they crossed the front lines. But it was necessary to hear also those machines that were flying at a great altitude out of ordinary ear range as they rushed on to attack some place far in the rear, in order that a general alarm might be transmitted by telephone. It was obvious that the ear must be reinforced, especially to detect machines at great height, and the apparatus to do this must be handled easily so as to give results quickly. Otherwise the planes travelling at their high speed would be out of range before they could be located. This called into being a new class of instruments which, although working under the laws of acoustics, were quite different in principle and detail from those employed in the sound ranging of guns.

While the naked human ear unaided has but little sense of direction, that is, it can tell only in an approximate way where lies the point from which any given sound is coming, it can with somewhat simple apparatus and with a little training be converted into a very satis-

factory and reasonably accurate instrument of direction. We are all familiar with the simple megaphone and how the voice can be directed toward any point; how the megaphone, if placed to the ear, will in like manner give a greatly increased volume of sound when it is pointed in the direction whence the sound is coming. With two horns, one connected with each ear, not only is much greater sensitiveness obtained but there is also a closer approach to directive accuracy, because when an equal volume of sound is heard in both ears it means that the horns are directed on the same point. This principle which forms the basis of underwater signals to ships where two sound receiving boxes, located one on each side of the bow, when they transmit equal volumes of sound indicate that the vessel is on a direct course to the origin of sound, formed also the basis for airplane detectors.

There were two types of apparatus. One type employed four horns in pairs, one pair determining the horizontal bearing of the plane as would be given by a magnetic compass, the other pair determining the vertical bearing of the plane; that is the vertical angle of the plane above the horizon, because the target being a point in space, both bearings were needed to fix the position.

The other type of detector was the paraboloid reflector. For those who have not investigated or who may have forgotten their conic sections, it may be permitted to recall that the parabola is a figure of such shape that parallel lines falling on it are deflected and concentrated at a single point called the focus. If a parabola be revolved about its axis the surface described is a paraboloid, a cup-shaped structure with flaring sides, which brings to a single point all parallel lines or rays falling within it. A paraboloid if of sufficiently large dimensions and made of material that would accurately

deflect sounds impinging on its interior surface, would evidently be a great sound collector and by placing the ear at the focus, sounds otherwise inaudible would become distinct. Furthermore, by slowly turning the apparatus first in one direction and then in another, it would be easy to recognize the moment when the maximum volume of sound was heard. At that instant the axis of the paraboloid would be pointed toward the point whence came the sound, and if the angles that the axis made horizontally with respect to some such line as the meridian and vertically with respect to the horizon, a single combined bearing would be given at once by which a search-light could be directed to the sound producer, in this case an airplane.

In actual practice it was found that a paraboloid with a diameter of nine to ten feet at the open end could be constructed that would answer all the requirements. If it were given free motion in all directions with scales reading the vertical and horizontal angles of the direction of the axis, an admirable airplane detector was produced. Of course, the ear could not be placed at the focus of the paraboloid, but two tubes like the tubes of a medical stethoscope, leading to the ears of the observer, answered the same purpose. To produce the best results it was necessary that the observer should wear a close-fitting head case, shutting out all sounds except those coming through the receiving tubes.

The French developed the paraboloid and the Corps of Engineers at Washington followed their lead. They succeeded in making improvements, for while the French apparatus weighed three and one-half tons, the American weighed but 1,300 pounds. This diminution of weight gave tremendously increased mobility, so very necessary for all articles connected with an army in the field. The American device could be set up and got into action in one-sixth of the time required for the French instrument.

The cumbersome weight of their paraboloid detector and its lack of mobility were fully appreciated by the French general staff, who experimented with other forms of sound-collecting apparatus. At the close of the war they had developed what was known as the Perrin telesitemeter, recognized as probably the best form of field instrument for the purpose. It was based on the double horn and binaural principle with the pairs of horns in nests. The total weight was about the same as the American form of paraboloid, but the weight of the heaviest part did not exceed 330 pounds. Two operators could take it apart in an hour and reassemble it in three hours. It was, therefore, the most mobile, the most easily worked and probably the most accurate sound detector in use.

Unfortunately with sound apparatus there were introduced chances for errors and the necessity for corrections not present when dealing with light. As the latter travels through space with such a high velocity and is not deflected from its straight path within the limits of the problem, all readings are made direct without correction for time or deflection. When dealing with sound there are many factors that must be taken into account, the neglect of any one of which would vitiate all accuracy.

In the first place the object is not stationary. Suppose an airplane be travelling at 100 miles per hour or at nearly 150 feet per second. If the plane were two miles high, there would be consumed nearly ten seconds before the sound reached the listeners' ears, since sound travels at the rate of about 1,100 feet per second, and in that interval the plane would have moved 1,500 feet from the spot where that particular sound impulse originated. It is also obvious that the amount of divergence is at the maximum when the airplane is flying directly across the field and diminishes according as the plane has an

ascending motion as well as a horizontal one, becoming zero when the plane is receding directly from the observer. A second source of error is the effect of wind which, by changing the velocity of sound increases or decreases in a complex manner, the difference between the actual and apparent position of the airplane. Then there are other corrections to be made for variations in temperature, humidity, etc., all of which affect the velocity of sound. These difficulties were one by one overcome until it finally became possible to locate within a comparatively small margin of error the position in space of a hostile airplane flying even as high as three miles.

In practice the method of operation was for an observer to listen for planes at night. As soon as one was heard notification was telephoned to other stations where all the listening sets were put in action. As fast as each observer got his sound range an assistant would read the angles, make the necessary corrections, give the bearings vertical and horizontal to the men with the search-light. The next instant a great beam of light, followed quickly by other beams from other search-lights, would flash into the sky. If the directions had been correctly given, there would appear a tiny bright spot in the black sky where the beams met, the airplane body reflecting the rays of light. Then, as the aviator would twist and squirm and dive to escape the disclosing glare, the "Archies" would open fire and there would be seen little brilliant scintillations as their shells exploded about the plane. At such a height and flying fast the plane usually escaped, although sometimes it would be seen tumbling over and over as it crashed to earth. But even if this last were not always the result the sound detectors at least stopped undue rashness, made the airmen fly high, rendering accurate bombing aim difficult, and permitted an alarm to be sent

westward, giving notice in ample season that every step might be taken to be ready to receive the nocturnal visitor in suitable manner.

To the spectator it was a wonderful sight, the brilliant beams from a dozen great search-lights concentrated on a single bright spot high in the air, alone, with shells bursting all about it, the quarry trying to escape the hungry guns. In the absorbing interest of the watching it was easy to forget that from the bright spot, in which were human beings for whom the apparently unequal struggle inevitably enlisted sympathy, there might fall at any moment a load of high explosives on the spectator's head. Even if that did not occur, there was always one thing that was certain to follow, and that was that the fragments of and the shrapnel from the protecting shells that were bursting so prettily overhead would soon be falling, and with results that might be equally disagreeable as those of an enemy bomb. But one rarely entertained such thoughts, so absorbing was the spectacle.

The work of Flash and Sound Ranging in the A. E. F. was entrusted to the Twenty-ninth and Fifty-sixth Engineers.

The development of the apparatus used in flash and sound ranging is a beautiful application of science to the art of war, as fascinating and as strictly theoretical as any work done in a laboratory. But the experiments finally producing the perfected instruments were not the only opportunities for research work leading to essentially practical results. As an illustration the Government report on America's Munitions records some interesting investigations made by an officer of the Ordnance Corps who in private life was nothing more warlike than a professor of astronomy in a large university, investigations which led to radical improvements in shell design. A certain make of shell intended for a

six-inch gun was found to give irregular and uncertain results in its flight. Major Moulton discovered that the cause for the inaccuracy lay in the rotating band, a band of copper encircling the lower or rear part of the shell which, engaging in the rifling grooves in the bore of the gun, gave the shell its steadying twist. The cold copper actually flowed backwards as the result of the propelling force behind the shell and raised an unsuspected flange sufficient to cause an uncertain air resistance that had not been allowed for in the calculations for trajectory. This led to a general study of shell design and it was found that the laws of mathematics governing the orbits of comets applied to the flight and trajectories of shells, and that, by giving shells a particular contour with a sharper point and more gradually tapered sides than the standard design, the air resistance was greatly reduced and the range of the gun correspondingly increased without change of powder charge. Thus the six-inch shell above referred to which had a range of 17,000 yards was given a range of 22,000 yards, while the 75 mm. shell had its range increased from 9,000 to 12,130 yards.

CHAPTER XX

ARTILLERY

While guns with their ammunition and service are not a function of the engineers, nevertheless through the modern development of quick-firing, long-range guns the science of artillery and of engineering have become very closely allied. If the actual training and firing of the pieces is no concern of the engineer, the mechanical details in their design and manufacture, their emplacements, shelter and transportation, the construction of points for observation, their protection by camouflage, the detection of the location of the enemy's batteries and other provisions for their effectiveness are distinctly so. Then the aiming of the pieces by indirect fire depends absolutely on the accuracy of the surveys and maps prepared by the engineers. In fact, the closest coöperation between the two arms has become of the highest importance.

Prior to the beginning of the war artillerymen failed to realize the possible development of their arm quite as much as the officers of other corps failed to do in respect to theirs. Although all military experts had agreed that, should a great war arrive, the part to be taken by artillery would far and away transcend that taken in any previous war, yet all their estimates fell far short of actualities. Not even the most enthusiastic supporters of the gun foresaw its possibilities, its application and above all the tremendous number of projectiles that would be consumed. The Germans came the nearest to doing so, but even they were wide of the mark.

In the American civil war approximately 5,000,000 rounds of artillery ammunition were fired on the Federal side during the whole four and one-quarter years. During the single year of 1918 the British and French armies alone expended nearly 13,000,000 rounds per month on the average. Or taking the maximum yearly expenditure in the former war, some 1,950,000 shots were fired, while in the twelve months that ended with the armistice the American, British and French guns in France were discharged more than 160,000,000 times. At Gettysburg, which has always stood in American history as a great artillery engagement, the Federal consumption of ammunition was 32,800 rounds. In the St. Mihiel offensive, where the artillery preparation lasted only four hours, after which the artillery work was intermittent, more than 1,000,000 rounds were fired, while the British guns in the Messines Ridge battle fired 2,750,000 rounds and in the battle of the Somme 4,000,000 rounds. In the above totals, shots fired from trench mortars and machine guns are not included, as they are not classed as "guns." These comparative figures take no account of the fact that the average weight of projectiles greatly exceeded the previous average weight. So that if a comparison were made of the total weight of metal fired in the two wars, the ratio would be still higher.

The weapons that did this tremendous execution were of many sizes, varying from little man-portable cannon capable of being handled by two men and firing a shell with a diameter of one and one-half inches to mighty pieces with a bore of sixteen inches, heretofore considered possible only on ships or on heavily constructed permanent foundations of masonry.

Artillery can be divided into two classes, mobile and non-mobile. In the former are all pieces that can be transported over roads and follow the movements of a

mobile army. The other class includes the larger weapons, which on account of size demanded special provisions for movement and could not be dragged gaily across open country. Thanks to the development of caterpillar tractor engines the maximum limit of the first class was greatly extended as the war progressed.

The characteristics of American field artillery are shown in the following table:

BORE OF GUN	WEIGHT COMPLETE	WEIGHT PROJECTILE	RANGE
37 mm ($1\frac{1}{2}$ ins.)	340 lbs.	$1\frac{1}{4}$ lbs.	2 miles
75 mm (2.95 ins.)	2887 lbs.	16 lbs.	$5\frac{1}{2}$ miles
4.7 ins.	9800 lbs.	45 lbs.	6 miles
5 ins.	23500 lbs.	.....	9 miles
6 ins.	41000 lbs.	.....	10 miles
155 mm (6 ins.) Howitzer	8000 lbs.	95 lbs.	7 miles
155 mm (6 ins.) (Long range)			
8 ins. Howitzer	19860 lbs.	95 lbs.	10 miles
8 ins. Howitzer	......	200 lbs.	7 miles
9.2 ins. Howitzer	......	200 lbs.	$7\frac{1}{2}$ miles
240 mm ($9\frac{1}{2}$ ins.) Howitzer	29100 lbs.	290 lbs.	$5\frac{1}{2}$ miles
	......	356 lbs.	10 miles

Note the comparative lightness of the field pieces.

A howitzer is a gun with a comparatively short barrel, giving a lighter and more mobile piece, but with a shorter range than the gun of the same calibre with a longer barrel. The difference in weight of piece and range between a " howitzer " and a " long " is clearly shown in the case of the 155 mm. guns.

The great variety in guns, and especially in substantially the same general type of weapon, was due to the different standards and units of measure of the three allied powers. The standard field piece of the American army prior to 1917 was a three-inch gun, as against a 3.3 in. gun in the British service and the 75 mm., the famous " 75s " or the " Soixante-quinzes " of the French. As our supply of field pieces in April, 1917, was absurdly

inadequate for our needs, it was wisely decided not to continue the manufacture of a gun that would not take the ammunition that could be obtained abroad and which our own factories were already equipped to turn out, but instead to build guns on the French model. As a matter of fact the French gun was a superior weapon, better than any similar gun in any army, better than the corresponding German 77 mm. piece.

The 4.7 inch gun was a standard American gun of excellence of which a certain number were on hand. The same is true of the five- and six-inch pieces, the latter, however, covering several different types of army and navy standards. They were used for a while and in limited numbers on account of our dearth of supply. The two eight-inch and the 9.2 inch howitzers were British types and were furnished to some of our divisions pending the delivery of the more effective 240 mm. howitzer.

American standards were thus reduced to the French types, which we copied, consisting of five varieties, the 37 mm., 75 mm., 155 mm., howitzer and long-range gun and the 240 mm. howitzer. Of these the 75's and 155's were the most important and formed the great bulk of the mobile artillery, one-half of the American artillery consisting of the former alone.

There is one feature that completely distinguishes modern guns from earlier types, and that is the mechanical means for absorbing the recoil. The gun in the previous states of the art was simply a barrel mounted on a pair of wheels, and the recoil of the firing was taken up by the gun kicking back into an anchorage in the ground, the aiming of the piece being disturbed each time it was fired. With moderate powder charges, with pieces that required some time to load and were aimed after each shot, the matter of gun " kick " with its disturbance of position was not serious. The quick-firing features of modern guns present a different situation. All modern

pieces can be loaded and fired with great rapidity, only a few seconds being required for the complete operation. To obtain the full measure of rapidity in firing, the time lost in re-aiming a piece after each discharge must be saved. To do this the recoil must be under control so as not to disturb the aim when it is once set, and permit the gun after each discharge to return automatically and exactly to its original position, requiring only reloading for the next firing.

A law of mechanics states that action and reaction are equal in amount but opposed in direction, which in the case of gunnery means that an amount of energy equal to that stored in the departing shell is expended in the recoil of the gun. Another law states that with a given weight of moving body the energy varies with the square of the velocity, that is, if the velocity be doubled, the energy is quadrupled, and if the velocity be increased fourfold, the energy is sixteen times as great. A shell leaves the muzzle of a 240 mm. gun with a velocity of a mile in a little more than two seconds, at which speed its striking energy is the same as that of a large locomotive travelling at the rate of more than fifty miles an hour. The striking force, the stored-up energy, of such an engine is mentally pictured when there is recalled the sense of power and rushing weight of a locomotive tearing past a railway station at high speed. Now imagine the stopping of that great mass of machinery in a distance of four feet and in one-half second of time without jar and without damage to the locomotive. Miraculous or impossible as it may seem, that is exactly what is done with the 240 mm. gun. By an ingenious arrangement of plungers compressing a liquid or air in cylinders, all requiring most accurate manufacture, the gun barrel slides backward on its mounting about four feet and then is returned automatically and promptly by the compressed energy in the cylinders to its original position

with its axis of direction absolutely unchanged. This great achievement was the work of a French engineer.

By means of the recuperator, as the device is called, a " 75 " can be reloaded and fired every three seconds, all shots being accurately directed on a target. A " 155 " is returned ready and reloaded in less than thirteen seconds, while even the largest guns, whose heavy ammunition requires more time to handle, can maintain a carefully directed fire at the rate of a shot in less than one minute. Furthermore, of such good material is the gun made that a 75 is capable of firing 12,000 rounds without losing its accuracy.

The 75's were usually drawn by horses, but the weights of the larger sizes were too great to permit them to be readily moved by animal power, and recourse was had to mechanical tractors, which represent one of the great advances in field work. Artillery to be effective must be mobile. Without the tractors the 155's would have been moved only with difficulty and the 240's not at all. Tractors weighing two and one-half, five, ten, fifteen and twenty tons were the adopted standards, nearly 25,000 in all having been ordered. They were of the caterpillar type, that is, they were propelled by two wide metal continuous driving belts, one on each side, and were capable of making ten or twelve miles an hour under favorable conditions. They could traverse the roughest ground and climb hills with a gradient of forty per cent. Then the principle was carried one step farther and guns as large as the 155 mm. howitzer were actually mounted on a self-propelling vehicle. Smaller guns, especially those used against airplanes, were frequently mounted on motor trucks.

With the fall of the massive gun emplacements in Belgium and northern France, attention was focussed on the possibility of mounting very large guns on specially designed railway cars, so as to render them both

safer against attack and more effective in attack by making them mobile. By such means the enemy could not reach them with other long-range pieces except by chance, nor ever be sure that he himself would not at any moment feel their crushing strength.

Early in the war both the British and French ordnance experts mounted naval and coast defense guns of calibre as great as thirteen inches on railway cars which were accompanied by other cars carrying extra ammunition and the gun crews. To support these monsters the engineers had to strengthen the bridges and lay track in the most substantial manner. The guns were so attached to the cars that the smaller pieces could be revolved on a pivot mount, giving an "all round" fire, while the larger ones were fired only lengthwise with the car. Some of these latter pieces had no horizontal adjustments, being held rigidly in the mounts with only vertical movement. Others were so mounted that they could be swung horizontally through a small angle to the right and left of the axis of the car. To provide for aiming these large guns at any target within a given area, a curved spur track would be laid, and the gun run on the spur to such a point on the curve as to bring the axis of the car pointing toward the target. If the gun were a rigidly mounted one, this spot would have to be determined accurately, but if the gun possessed a small horizontal movement on its own mount, nice adjustment of aim was more easily obtained by swinging the gun through a small angle after the car had been placed in approximately correct position. The British authorities pushed this idea of mobile artillery to the limit, using even the light railway cars. It was found quite feasible to mount, transport and fire guns of as large a calibre as six-inch from the little cars on the 60-cm. tracks, and when hostilities ceased plans were in hand with every assurance of success to mount guns as large as eight-inch

on light railway cars. Our own Ordnance Department was experimenting along the same line and contemplated using twelve-inch rifled mortars on such mounts. The advantage of such mobility with the further great benefit of freeing the highroads of slow-moving, encumbering and highly destructive vehicles is readily appreciated.

The American Ordnance Officers had from the beginning of the war been studying the possibility of mounting very large guns on cars; in fact, certain reports were made, even before 1914, suggesting such a plan for sea coast defense. During the Civil War a few mortars, very insignificant pieces as compared with the rifled cannon of to-day, were set up on flat cars. When the United States declared war the Ordnance Department made an investigation as to how many large guns could be obtained that might be sent abroad and there be mounted on cars, because special guns of such size would take too long to manufacture to be of early use. More than 300 guns varying in size from seven-inch to a huge sixteen-inch howitzer, and more than 100 rifled mortars, some belonging to the Navy, others intended for coast forts, were found as possible of use. The Ordnance Department commenced at once the mounting of these guns on cars and had made great progress when the war ended, although only three eight-inch units were actually shipped abroad.

But the Navy Department, having on hand some fourteen-inch guns, did succeed in mounting them and shipping them to France in time to take part in the Argonne-Meuse offensive. From the beginning of hostilities the Germans had been able to outrange the guns of the Allies. Exclusive of the "Big Berthas" with which they bombarded Paris at a distance of seventy-five miles, a phenomenal performance, although more spectacular than practical, the longest ranged guns on either side were those the Germans established near Ostende,

AMERICAN ENGINEERS REPAIRING A CAPTURED GERMAN RAILWAY YARD WHICH SHOWS THE EFFECT OF LONG RANGE BOMBARDMENT

and which threw shells into Dunkerque — a distance of 50,000 yards or nearly twenty-nine miles. The British and French had some guns of twelve- and thirteen-inch calibres mounted on railway cars but with a maximum range not exceeding twenty miles and there was needed something more powerful but still fully mobile with which to reach the German back areas, especially such targets as railway junctions or large ammunition dumps.

These American naval guns weighed nearly 100 tons each and had a length of fifty calibres, that is fifty times the diameter of the bore. To make them effective they must be mounted on and fired from railway cars. The year 1918 had begun, the guns were still in the United States and not even a design for a railway mount of such capacity was in existence. In fact, it was very doubtful whether a satisfactory mount could be designed at all, and even if designed, it appeared almost impossible that it could be constructed in time, so that the guns and mounts could be sent to France to take part in the coming crisis. But this astonishing feat was accomplished by the Ordnance Department of the Navy, and the construction was carried out by the Baldwin Locomotive Works and the American Bridge Company, the first mount being delivered in the incredibly short time of seventy-two days.

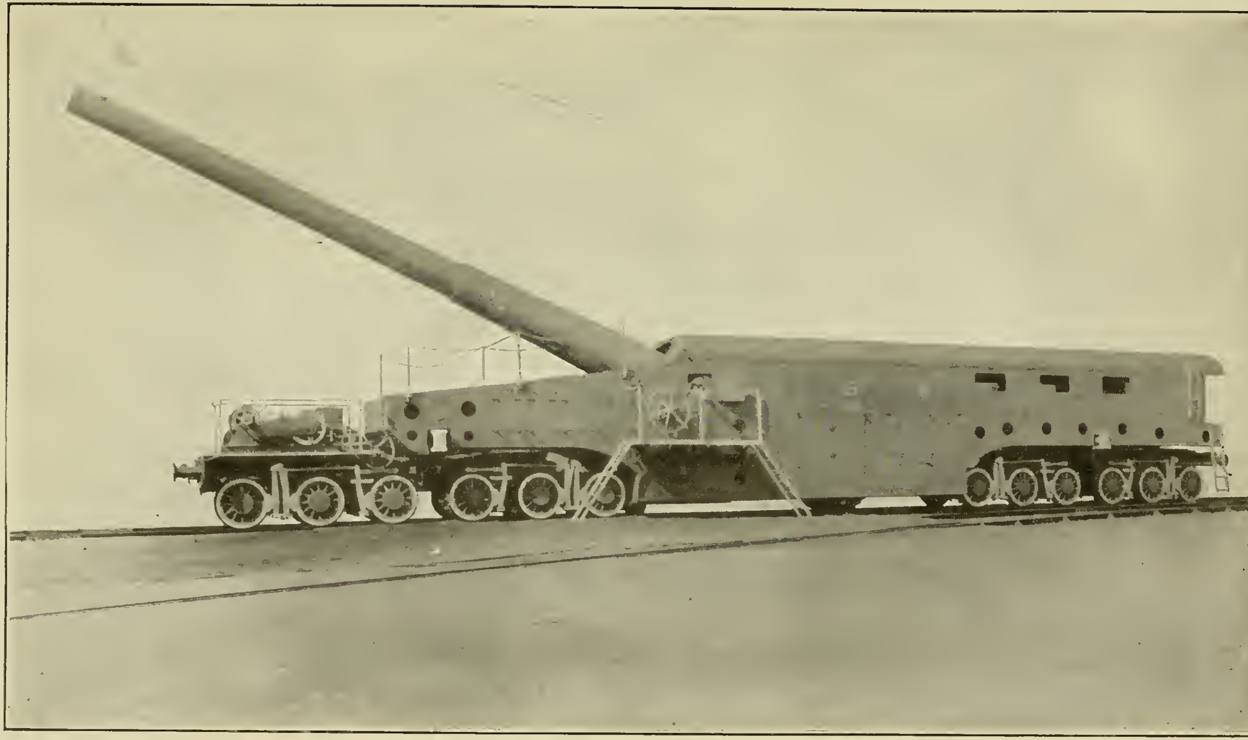
The extraordinary car on which the guns rested was supported on two pairs of six-wheeled trucks, or twenty-four wheels in all, one pair of trucks being at each end of the car. The total weight of gun and car was 535,000 pounds or 267.5 tons, of which the gun constituted 192,500 pounds, and the car 342,500 pounds. The gun was so mounted that with an angle of elevation not exceeding fifteen degrees, at which elevation it had a range of 23,300 yards or more than thirteen miles, it could be fired with no other support than the car and trucks, the horizontal component of the reaction being

taken up by the car brakes and friction, the car sliding backward on the rails. As the gun under these conditions had no means of lateral adjustment, the car had to be replaced in a predetermined exact spot on a curved track after each shot to get the correct aiming. However, by using a special foundation beneath the car the gun could be elevated to forty-three degrees, giving an effective range of 45,000 yards or nearly twenty-six miles.

This foundation consisted of a pit into which the rear part of the gun support dropped as the piece was elevated. The gun support was then firmly braced against timbers at the back of the pit to give rigid resistance when the gun was fired. When the gun car had been run over the pit, the weight of the gun was transferred by jacks from the car to the specially prepared platform. After lifting the gun from the car it could be given a horizontal movement through two degrees thirty minutes on either side of the axis of the car, thus permitting accurate adjustment of aim.

When the gun was fired from the car without other support, the pressure on the centre bearing of the rear truck was increased from a dead load of 180,470 pounds to 315,160 pounds, each axle transmitting 62,000 pounds to the rails. When the gun had the maximum elevation of forty-three degrees, the pressure on the main resisting casting was 772,000 pounds. These weights and pressures give an idea of the problem solved by the engineers in designing the car. When the car was rigidly held and the thrust of the recoil was taken up by the pit timbers the recoil mechanism, which absorbed the shock, was so neatly adjusted that the ponderous weapon had a movement of only forty-four inches. After each discharge it was at once and automatically returned to battery, with true aim unaffected.

The powder charge weighed 480 pounds and the projectile 1,400 pounds. The latter left the gun with a



UNITED STATES NAVY 14-INCH GUN ON A RAILWAY MOUNT. THESE GUNS RENDERED GREAT SERVICE IN SHELLING ENEMY BACK AREAS AT A RANGE OF MORE THAN 20 MILES DURING THE ARGONNE-MEUSE OFFENSIVE

velocity of 2,800 feet per second or at the rate of considerably more than a mile in two seconds or more than two and a half times the velocity of sound. So accurate were these guns that four shots fired on a French proving ground at a range of 29,000 yards showed an average variation of only fifty yards.

The complete outfit for each gun consisted of one locomotive, one gun car carrying the gun, and ten other cars, some with living accommodations for the gun and train crews, others for ammunition and equipment for the construction of the pits and special foundations.

The battery personnel exclusive of the train crew consisted of four officers and sixty-seven men. There were five such trains, each of which was a complete, self-sustained, mobile unit. In addition to the five battery trains there was a staff in a headquarters train, composed of one locomotive and seven cars, carrying the officer commanding all the guns, his staff, and the extra hospital service.

The mounting of great guns on railway cars imposes no limit on the size of the gun that can be mounted, certainly not as the size of guns is viewed to-day. That being the case, the thought naturally comes, will the military engineer, when hereafter planning coast defenses, continue to suggest isolated expensive forts with rigidly fixed emplacements? Forts whose positions are accurately known can be reached by an unseen enemy on land or sea, an enemy to whom no reply can be made, as his position is not quickly ascertainable. With this in view will not the engineer be inclined to build railway tracks, or use the lines of existing railways, constructing occasional spurs along such portions of the coast or frontier that he wishes to protect, and on which tracks he can move his great guns at will? The cost of one permanent fort will pay for many guns and cars.

Against these mobile units an enemy can no longer

attack at will the points of defense, because such points being constantly moved, their position will never be known. Such tracks would permit the concentration of defensive energy at any place or places, and the immediate removal after a decisive blow had been dealt, or should a frontier be forced, the complete withdrawal of the main defenses to new positions.

The efficacy of mobility as contrasted with the old military conception of defense in rigid immobility is well illustrated in the French defense of Verdun, one of the triumphs of the war and at the same time a great engineering achievement.

Verdun was one of a great chain of fortified points with Belfort, Nancy and other cities facing the German frontier. There was a central citadel and, encircling the city on the north and east sides, a group of forts, each constructed of massive masonry and earthworks, with deep moats for protection against assault, all mounting heavy guns. With the fall of the Belgian fortresses the French were quick to see that places like Verdun, in spite of all the thought and labor expended on them, were far from being impregnable, and seeing that, they were quick to act. Many of the guns were removed from their rigid emplacements and mounted on cars that permitted them to fire from one point to-day, from another to-morrow. Then they dug trenches and relied on a mobile army for the defense of Verdun. In February, 1916, the enemy attacked in unparalleled force.

Verdun, before the war, was served by two double-track railways of importance. One reached it from the south, running down the valley of the Meuse, the other, the main line from Paris, turned from the valley of the Aire at Aubreville, and thence ran due east to Verdun. These two routes were, therefore, substantially at right angles to each other, Verdun being at the point of the angle. There was a third line, a local railway with a

gauge of one meter, that reached Verdun, but on account of heavy gradients and its single track was not given serious consideration as a carrier.

When the German wave rolled south in 1914, it passed to the westward of Verdun and some miles beyond the railway running through Aubreville, Verdun holding as an outpost. After the battle of the Marne the German line fell back north of the Aubreville railway but remained south of Varennes. Then in October, 1914, a drive was made east of Verdun with the intent of breaking its defenses, an attack that resulted in the occupation of St. Mihiel and the creation of the annoying salient across the Meuse, which included within its limits four miles of the railway, the main highroad and the canal leading to Verdun. This salient the enemy held until they were forced to evacuate it by the American offensive beginning September 12, 1918. Verdun was thus reduced to depend on the one railway through Aubreville. In February, 1916, the great struggle began for this key to the gateway to eastern France. Time after time, as fast as the French would rebuild the railway, the Germans would again cut it with artillery fire in the neighborhood of Aubreville whence their front line was distant but four miles. Finally the French, with much reluctance, gave up the effort to operate the line and began the seemingly impossible task to supply the army holding Verdun by means of the meter gauge line and such traffic as could be taken care of on the cross-country highways. By straining all facilities to the utmost, they succeeded in sending daily to Verdun 2,000 tons of supplies over the little railway and almost the same over the road in motor trucks, but that was not enough. If the fortress were to hold out against the continued enemy attack, more food, ammunition and other supplies would be consumed than that amount, while any break in the line would spell immediate disaster. The

engineers undertook to solve the problem by constructing a new standard gauge railway, sixty kilometers long, located midway between the two main lines and out of reach of the German guns. This they accomplished in three months. The rest is known. Verdun, thanks to the ability of the French engineers to mount the guns so as to be mobile and to construct the railway, held out and was never taken in spite of a succession of attacks involving unstated losses to the besiegers.

Thus the gunnery experts and the engineers have worked together in the design of the weapons, in the production of special steel, in the manufacture of the guns and parts, and finally in their manipulation in the field. How they further coöperated in the determination of range, in the protection of their own batteries and the detection of the enemy's is another story and was told in the previous chapter.

CHAPTER XXI

LIGHT RAILWAYS

For many years all military men had been aware that at the very front along a battle line there would be needed a system of rail transportation of lighter construction than a standard gauge line, one with smaller cars and narrower gauge, one that could be laid quickly and perhaps as quickly removed. They saw that such a railway by its mobility and elasticity would be better adapted to serve the scattered and smaller local needs of a fighting army in the field than a standard gauge line with its stouter construction and heavier equipment. But as was the case with many other engineering features, the military men failed to realize fully what an important function these little railways would fill in a modern war.

Even as late as 1916, when the United States was on the very verge of declaring war, the Corps of Engineers produced an excellent handbook on railways of which but fourteen small pages were devoted to this important branch of military railway engineering, although it spoke of these lines whose " possibilities for both offense and defense are very great and have never been fully utilized." It is amusing now to recall that less than two years after those words were written, the United States had nearly 14,000 men endeavoring to utilize the same offensive and defensive " possibilities " but on a far greater scale than anyone in 1916 could picture even in his wildest imagination.

The American handbook on Military Railways named these small lines " combat railways," not a particularly happy term, because at times standard gauge railways

were used as such, and fixed no definite gauge for them, though suggesting one of two feet, or two feet six inches. Even when war was declared there was no adopted or recommended gauge for American " combat railways " and there was no equipment on hand.

In the Russian-Japanese war narrow-gauge railways were made use of by both belligerents, the Russian gauge being 75 cm. (2 ft. 5½ in.) and the Japanese 60 cm. following the accepted standard of their German instructors. In Europe both Germany and France had given the question much study and they had each adopted a gauge of 60 cm. (1 ft. 11½ in.) as the most suitable. The British had previously decided on a gauge of two feet, which was close enough to the continental gauge to permit such equipment as they had on hand to be worked in connection with it without confusion until new 60 cm. rolling stock could be constructed.

The French called these little railways " voies de soixante," using the dimension of the gauge for a name which was shortened into " une soixante " or " les soixantes " for singular or plural. The British gave them a generic appellation of " light railways," which name was adopted by our own forces when we came to establish a narrow-gauge service, although, of course, our lines were constructed to the French gauge of 60 cm.

The field where these light railways were used most was at the very front. The ordinary standard gauge railways, or broad gauge as they were usually called to distinguish them from the light railways, were never or very rarely used within possible observation by the enemy or within the range of his light artillery. The point on each broad-gauge line where traffic ceased was called a rail-head, developed in practice into a terminal transfer yard with some warehouse capacity for perishable goods. These rail-heads were usually from five to ten miles behind the front lines and, therefore, within

AMERICAN ENGINEERS CONSTRUCTING A LIGHT RAILWAY THROUGH A FOREST WHERE IT COULD NOT BE DISCOVERED BY ENEMY AIR OBSERVERS

reach of long-range guns. To avoid a great disaster in case of being shelled, concentration of supplies was avoided as much as possible and such supplies as were held in storage were distributed into different "dumps" according as they consisted of engineer, ordnance, quartermaster, or commissary matériel with ammunition always by itself.

The rail-heads were so laid out that access to the storage houses, storage places or cars could be had either by motor truck or light railway trains. For the latter the most convenient arrangement was to have a broad-gauge track on one side of a warehouse, unloading platform or open storage space and a light railway track on the other. It was rarely economically possible to transfer loads directly from broad-gauge car to light railway car.

From these rail-heads the light railways reached out in all directions, carrying supplies to small scattered forward dumps and the ammunition to the front trenches or to battery positions. In short, it might be said that they did the retail delivery work, leaving the wholesale business to the broad-gauge lines.

The track was composed of the ordinary T-shaped rails laid on steel or wooden crossties. The rail varied in weight from fifteen to twenty-five pounds per yard. The lighter rails were used in the early days when experience was lacking, but as traffic increased and the possibilities of the light railways were recognized, heavier rails were called for until finally it was the consensus of opinion of the American, French and British engineers that there was no economy from any point of view in laying rails of less weight than twenty-five pounds per yard. They gave a more resistant track against heavy traffic, and the extra weight did not prove to be a serious or even appreciable handicap in rapid track laying.

French track was made up in sections five meters long,

the rails being riveted to steel ties. Some of the track sections were curved to radii of 30 and 50 meters to save bending rails in the field. The British, though using some metal ties, preferred those of wood four inches wide by six inches thick and four feet long. The American sector being a part of the original French front, much of the light railway track was of French standard practise. On new work the American Engineers preferred wooden ties with rails thirty feet long, bending them in the field to fit any desired curve. When American steel ties were used, they were generally held to the rails by clips and bolts rather than by rivets, and they were attached as the track was laid. This arrangement of non-connected parts made the actual work of track laying a little slower, an objection that was offset by the greater ease in shipping the rails, fastenings and ties separately, and the greater convenience in storing the track material in engineer dumps.

The rolling stock presented many interesting features. Locomotives were of two classes, those that burned coal and consequently gave off smoke and those that did not. So long as the light railways were not hidden from observation, it was possible to use locomotives of the first class, the preferred type on account of the simplicity of the mechanism and the ease of repairs, but when they approached the actual front positions they were no longer safe. For even if the tracks were sheltered from direct sight, the ascending smoke would disclose the presence of a train. As all such trains were suspected of being loaded with ammunition and most of them were, the first signs of smoke were apt to draw the fire of the enemy.

As the location of all railway tracks, broad or light, were known through aerial photographs and accurately plotted on the maps, enabling the range of every yard

of track to be computed with respect to every battery, it was an easy thing to hit a train even in motion if only the smoke of its locomotive disclosed its presence.

For the forward portions of the line gasoline motor locomotives or gasoline-electric motors were used. In the latter a gasoline engine drove an electric generator. Although there was a duplication of motor engines with some loss of power in the transformation by passing the developed energy through the medium of electricity instead of using it directly after its first production, in the gasoline engine there were certain mechanical advantages that were held by some to be compensatory. For example, variation in speeds could be controlled without changes in gears, and a higher tension pull was obtainable by a rotary than a reciprocating engine at the moment of starting. The American locomotive designers decided, however, that the disadvantages due to the great complication of the intricate machinery were paramount and no engine of the combined type was built for our own service.

So long as intervening ground shut off direct observation, trains drawn by these non-producing smoke locomotives were reasonably safe, even in daytime, except against a chance shot or detection by airplanes overhead. If, however, the tracks were visible from the enemy observation posts, traffic on such parts of the line had to be handled exclusively at night.

Of steam locomotives there were several varieties, with a total weight varying from about 14,000 to 36,000 pounds and with different combinations of driving and non-driving wheels, or as expressed in the usual terms, 0-4-0, 0-6-0, 0-8-0, 0-4-4-0, 2-6-2 and 4-6-0. To the non-professional reader it may be proper to explain that the first and last figure of each series gives the number of wheels in the guiding or trailing trucks, and the intermediate figure or figures the number of connected driving

wheels. Thus 0-4-0 means that the engine is mounted on only four driving wheels, that is, on two axles; 4-6-0 indicates an engine that has ten wheels, four of which make up a front guiding truck, behind which are six driving wheels with no trailing wheels. Inasmuch as the United States entered the war without any light railway equipment and, therefore, without prejudice, the American engineers were free to design their own equipment. After taking full advantage of British and French experience which was freely offered, the type of engine finally adopted as the American standard, probably represents the most satisfactory type. This machine was a saddle-tank engine, but with the tanks carried as low as possible, a most important detail, for otherwise the elevated center of gravity greatly increased the natural instability of these machines on the narrow gauge. The wheel arrangement was 2-6-2, giving a guiding axle on both ends with three driving axles, making a combination particularly well adapted for running in either direction over rough track. The front and trailing trucks guided and steadied the engine and also gave opportunity for the maximum boiler and tank capacity within the limited weight permitted on the driving wheels. The total weight of the engine was 33,700 pounds, distributed as follows:

On front truck	5,000 lbs.
On driving wheels	23,100 lbs.
On rear truck	5,600 lbs.

The total wheel base was fifteen feet seven inches, of which the rigid driving base was five feet ten inches. The diameter of the driving wheels was twenty-three and one-half inches, while that of the truck wheels was sixteen inches. The cylinders were nine inches by twelve inches, and the fuel and tank capacity were 1,700 pounds and 476 U. S. gallons respectively.

The French operated a peculiar type of engine to which they were much attached. This locomotive, known as the Pechot, had two boilers served by a single fireman. It weighed 28,000 pounds and rested on eight driving wheels which, coupled in pairs, were so independent of each other that the rigid wheel base was less than twenty-eight inches. It possessed many advantages in light railway work, including great facility in operation over a rough and tortuous track, and being built in two units, either or both could be used for power, thus conserving fuel. Either engine could function even if the other had been damaged by shell fire. Furthermore, since the fire box was in the centre, no matter how steep the gradient, the water always maintained the same elevation at the center and, therefore, always covered the crown sheet.

Gasoline locomotives were smaller than the steam locomotives, as there was less need for large power at the immediate front, the trains being lighter. The United States had two types of gasoline machines which were fairly typical of general practice. They were of the same wheel arrangement, namely, four driving wheels without leading or trailing trucks. The distinguishing feature was their weight, one weighing 10,000 and the other 15,000 pounds, with the following comparative details:

Total weight	10,000 lbs.	15,000 lbs.
Length...............	10 ft. 9 ins.	13 ft. 0 ins.
Width................	4 ft. 7½ ins.	5 ft. 2 ins.
Driving wheel diameter	24 ins.	30 ins.
Wheel base, length....	3 ft. 0 ins.	4 ft. 0 ins.
Speeds in either direction................	2 speeds 4 and 8 miles	
Fuel tank capacity.....	25 gals.	30 gals.

Cars were for the most part of the gondola and flat types, for the easy loading of heavy material for short

haul, the former alone constituting nearly one-half of the whole equipment. There were also box cars and cars for special purposes, such as tank cars for hauling water. The cars were about twenty feet long and were mounted on two four-wheeled bogie trucks, giving great flexibility on curves. The normal carrying capacity of the cars was 22,000 pounds and the cars themselves weighed, empty: flat cars 8,000 pounds, gondolas 9,000 pounds, boxes 12,000 pounds. These standards were substantially the same in the French and British services as well as the American, though the German cars had one-half the above nominal capacity and weighed about one-half as much. The wheels had a diameter of fifteen and three-quarter inches and the truck wheel base was three feet, the trucks being fifteen feet apart, center to center.

As to the construction of these light railways there is little to be said, except that every effort was made to eliminate heavy work so as to advance track laying with rapidity. On account of the narrowness of the gauge, sharp curves could be and were freely used, radii as short as 100 feet giving no trouble in operation. As trains were usually short, gradients steeper than what would be desirable on main lines were permissible. Usually a maximum of 2.5 per cent was fixed for light railway gradients but in exceptional cases rates of climb as high as three per cent or even four per cent were encountered. The last two were, however, exceptional.

The soil of France is usually of a clayey nature, so that all roadbeds had to be well drained and the track stone ballasted. Without such ballast it would have been impossible to maintain a usable track composed of light rails and small ties. It was on this account that the British engineers advised that wooden ties be used rather than the built-up, ready-to-lay track, in accordance with French practice. They gave a better bearing, and if the

ground were very soft or muddy, larger ties could be used in an emergency.

Derailments were not infrequent. The saddle-tank locomotives with their high center of gravity gave much trouble if the track were rough, resulting sometimes in the whole engine toppling over. But in spite of such annoyances and the smallness of the equipment the amount and extent of service rendered by these little railways were very remarkable. A wider gauge would have made the locomotives more stable, would have reduced the number of derailments and would have enabled heavier trains to be run. For these reasons a gauge wider than two feet was recommended by some engineers. The function of these light railways, however, was to be really light. They were intended to serve only as local distributors and were not intended to attempt the heavy service, properly the function of the broad-gauge lines. A wider gauge would have meant heavier track, equipment with more elaborate construction and an invasion of the field occupied by the larger lines. The true principle to follow, under conditions as they existed in France, is to maintain broad-gauge rail-heads as far advanced as possible, to carry supplies to such points in train-load lots or as near full train loads as is feasible, and then to rely on the little lines to do the local distribution and delivery beyond.

The original purpose of a light railway was to deliver heavy ammunition to forward battery positions. Such material was awkward to handle in motor trucks and still more so in horse-drawn wagons, the chief means of transportation at the beginning of the war. It was for the reason that their chief function was in connection with the guns that French light railways, though constructed by the engineers, were operated by a special railway corps attached to the artillery arm. Their scope of service, their utility to all other arms carried the

development of the light railways far beyond any estimate conceived during the first part of the late war of what they should do or even were capable of accomplishing. As indicating the scope, variety and extent of the traffic, the distribution of the tonnage, equating troops in tons, hauled on the American light railways during the autumn of 1918 when the great St. Mihiel and Argonne-Meuse offensives were being carried out was per week:

Ammunition	5,000 tons	
Engineer matériel	2,900 tons	
Forage	1,300 tons	
Rations	3,500 tons	
Water	1,000 tons	
Personnel	1,700 tons	
Road matériel	4,600 tons	
Other army tonnage	2,600 tons	
Total army tonnage		22,600 tons
Light railway matériel		12,400 tons
Total tons per week		35,000 tons

These figures were not maxima, because during one week, while the Argonne offensive was at its height, no less than 10,000 tons of ammunition alone were sent forward. But large as this last figure is, it was exceeded nearly fourfold on the system of British light railways that supplied their five armies. It must be remembered that on account of their older and broader establishment, both the British and French systems of light railways were more complex, more completely laid out and did a heavier traffic than our own.

The large amount of light railway matériel transported was due, of course, to the rails and ties required

in the construction of new or the repairs of old lines, as the army advanced.

For those who are interested in statistics of train operation the above American tonnage was handled on 554 kilometers (335 miles) of main line. The ton-kilometers were 584,000, the train-kms. were 21,800, the locomotive-kms. 44,500, the loaded-car-kms. 80,800 and the empty car-kms. 52,200. The average haul of a ton of freight was 16.7 kms. These figures gave 26.8 ton-kms. per train-km. and 1,050 ton-kms. per kilometer of line.

Nor were individual loads negligible affairs. In one instance one of these little cars, supposed to carry only 22,000 pounds, was actually loaded with 400 complete rounds of 155 mm. shells, weighing 45 kilos (99 lbs.) each, a total of nearly 40,000 pounds. In another case when an emergency was pressing, a train of eight cars was moved 40 km., each car containing 365 large shells, a net weight per car of 36,211 pounds, while a 426 cm. (16¾ ins.) gun weighing 74,710 pounds was shipped on three cars.

The light railways were not restricted to freight. It was found that troops with their equipment could be more easily moved on such trains than in any other way. Divisions in the front trenches were always relieved at night, in order to avoid attracting enemy notice at what was always a critical juncture. While this was being done it was essential that the outgoing troops should be withdrawn as rapidly as possible to avoid confusion or interference with the division moving in to take their place. Under such crcumstances all available means of transport were called into requisition. Miles of old Paris and London busses, painted a dull grey, with every outward vestige of previous life on the boulevards or Piccadilly obliterated, proved exceedingly convenient. But the little railways did their part, too, so well that

23,000 men with their arms and other equipment were moved in one relief, during five nights, with more than 6,000 men during a single night, this in connection with other traffic.

The use of the busses gave an opportunity to coin new words, and very useful ones, too. The loading and unloading of troops were referred to as "embussing" and "debussing," following the form of entrain and detrain.

Reference has already been made to the placing of guns on the little cars and to the still more ambitious plans for the mounting of very large pieces that were cut short by the signing of the Armistice.

But the British inaugurated a new step and used the light railways to transport wounded. They believed, as the tracks of these local lines reached all points along the front, that during and after an engagement wounded men could be carried in railway cars more readily and more comfortably to receiving hospitals than in motor ambulances on the highway. On the road they would be subject to annoying if not serious delays by the front-ward flow of road traffic, traffic that could go by no other means. To make a practical test, they connected two large receiving hospitals, or casualty clearing stations as they were officially named, with the whole network of light railways serving that particular front, just prior to a major engagement that they knew was to take place. Several trains of cars were fitted with racks to hold the stretchers. The wounded could thus be and were taken directly from the field, placed on a waiting train and delivered to the hospital without further rehandling and probably in less time than was possible by using the ordinary road ambulance service.

The innovation worked well, the men arriving in good shape and with much less delay than on previous occasions. But during a lull in arrivals the surgeon com-

manding, seeing an intelligent-looking sergeant on a stretcher, thought to ask his impression of the method. "It is very good, sir! The service is excellent, but if I might be permitted to criticize anything, I do think the speed was a bit rapid." The surgeon was surprised, because he had given strict orders that the speed should not exceed ten miles per hour, realizing that any speed faster than that on the rough track and over the poor springs of the cars intended primarily for heavy freight, would injure the wounded. So he sent for the locomotive driver who had just brought in the train. Now it happened that the crew of this train consisted of Americans. "Were you the driver of the last train to arrive?" asked the surgeon. "Yes, sir," was the reply. "What speed did you make?" "'Bout forty" came the startling answer. "But surely you had orders in regard to speed limit?" "Oh! yes," said the driver. "I was told to go and to get there." With Yankee nerve he "got there." How the train kept the rails at such a speed around curves with radii of 100 feet is still a mystery, but at least it justified the restrained criticism of the wounded sergeant as not being an exaggeration that the speed was a "bit rapid."

These little railways were nearly all single-track lines, and as there were frequent junctions, few regular stations and no time tables, train dispatching was no easy matter. The only way by which trains under such circumstances can be handled is by the aid of a well constructed telephone system with boxes set along the track at short intervals, from which train crews can call up headquarters and get their orders. The regiments that bore the burden of light railway work were the Twelfth and Fourteenth Engineers, who were continuously engage in such work from August, 1917, and always in the advanced area.

When hostilities ceased, the American light railway

system consisted of about 2,240 kilometers (1,350 miles), of which 280 kms. had been inherited from the French as different parts of the front were taken over, 200 kms. had been constructed by American engineers and 1,740 kms. were German lines captured in the advance in the Argonne-Meuse and St. Mihiel offensives. During these offensives the average number of kilometers operated was 554, and the maximum force engaged was 13,650 men, of whom more than one-half were occupied on construction, so great was the demand for new lines or the rehabilitation of the old as the advance progressed.

The equipment consisted on November 11th of about 300 locomotives of which about 160 were worked by steam and 140 by gasoline, with approximately 1,600 cars. It is difficult to give exact figures regarding the equipment in actual service as more than the above numbers of locomotives and cars had been shipped to France and were being set and sent to the front as rapidly as possible, though many locomotives and cars had not left the port of entry when hostilities ceased. Thirty-three steam and fifty gasoline locomotives as well as 358 cars were captured from the Germans.

Following the practice of the French and the British, the American engineers established a complete central repair shop with a full assortment of special machine tools, where all repairs of every nature could be made to any class of rolling stock. The parts and the dimensions of the parts of locomotives and cars differed so much from those of standard gauge stock that there was no advantage in combining the repairs of standard and narrow-gauge equipment in the same shop or shops. It was found better to give each class of equipment its own separate repair facilities, equipped with special tools, operated by a personnel experienced in each particular class of rolling stock and where the different kinds of spare parts could be stored by themselves. Any attempt

at combining in one shop the work of repairing two such distinct types of vehicles, as locomotives or cars used on broad- or narrow-gauge railways, resulted in confusion and lost motion.

In short, the Lilliputian railway that at the beginning of hostilities was little more than a toy with apparently limited possibilities, had grown into a very husky system and was a very potent factor in the solution of the problem of transportation, nearly always the greatest problem that the engineer has to face no matter what the character of the work. The driving of a tunnel, the operation of a steam shovel or dredge, depend upon how fast cars or scows can be delivered empty and taken away loaded. The capacity of the excavating machines themselves always exceeds that of the attending transportation units. So it is with an army under modern conditions of war. An army is dependent absolutely for its fighting efficiency upon transportation facilities, and its demands in this line exceed the possibility of supply by such railways or highways as are available even in such a well equipped country as France. No matter what the amount of transportation facilities that are ready at hand, they will be found in a great measure to fall lamentably short of actual requirements. In studying the needs of future wars and making provision for them, transportation should be and undoubtedly will be one of the major subjects to engross the attention of the authorities, and to a far greater extent than ever before.

The method of administration of light railways differed radically in the three chief allied nations on the western front. As explained above, the French lines were built by the engineers but operated under the artillery arm. The British organization consisted of a directorate or section of the Department of Transportation, administered by an officer who happened to have the rank of brigadier-general, with the title of Director of Light

Railways (D. L. R.). He reported to the Director General of Transportation (D. G. T.) and had charge of all matters concerned with these little lines, whether of construction, operation, or maintenance of either equipment or permanent way. This authority was extended over the lines in the army area as well as those in the rear.

To keep liaison with army requirements an Assistant Director was attached to each army headquarters and another officer junior to him at each corps headquarters. These officers working in close coöperation with the army and corps commanders saw to it that army needs were cared for, but they remained under the direction of the Director of Light Railways, calling on him for all rolling stock, track and other matériel, and additional troops for railway service, if they were needed. This arrangement had two great advantages. Firstly, the demands from the several British armies, of which there were five, were coördinated through the Director of Light Railways and adjusted by him in case of conflict. Secondly, the fact that the Director was a member of the transportation department, ranking with the directors of other transportation services, all of whom reported to one head, the Director General, assured that the demands of the Light Railway Section as a whole received attention at least equally with all other transportation demands. In the event of a shortage of supplies or labor, the most pressing needs of the entire system were satisfied in their order of importance. The British organization was based on the principle of centralization.

The American method was the converse. Here the view was taken that, as the light railway lines lay wholly within the army area, the entire system operating beyond the broad gauge rail-heads was an adjunct of the combatant forces, intended to keep them supplied with ammunition, stores and engineer matériel used in their operations. It was held that the army commander,

advised by his corps commanders, was the best judge of army needs, and that to refer matters back to General Headquarters involved certainly a loss of time and possible conflict of judgment, either of which might be exceedingly serious during a period of important military operations. At such a moment action must immediately follow decision whether right or wrong.

In the first organization of the Transportation Department, as was explained in detail in Chapter VII, there was a Manager of Light Railways on the staff of the Director General of Transportation, following the British principle of centralization. In the subsequent reorganization of the engineering department in February, 1918, the section of Light Railways was taken from the Director General of Transportation in accordance with the decision to separate the army service from that of general transportation. It was raised to the dignity of a separate department, being combined with the work on roads, and was placed under a Director of Light Railways and Roads who reported to the Chief Engineer.

In August, 1918, when the First Army was organized the authority of the Director of Light Railways and Roads was reduced substantially, being limited so far as light railways were concerned to the control of the central repair shop at Ablainville, the general stores, and the tracks leading from them to the advanced system. Within the army areas all control, not only of light railways but also of roads, passed to the Chief Engineer of each army who acted through an Engineer of Railways and Roads. From this latter officer all troops assigned to light railways in the army area received instructions. It was he who decided all matters of construction and who had charge of operation.

In September, 1918, a Table of Organization was issued by the General Staff which defined the light railway service for each army as consisting of:

Five light railway regiments, each of two battalions of engineers (each first battalion composed of three operation companies and one advanced shop company, and each second battalion composed of two maintenance of way companies and one construction company).

One battalion (three companies), shop men for central repair shops.

Eleven service battalions (four companies each).

There was also a road service laid out for each army as follows:

Five battalions engineers (roads) (four companies each).

Ten truck companies.

Five wagon companies.

Eight service battalions (four companies each).

Two battalions engineers (quarry) (four companies each).

Three service battalions (quarry) (four companies each).

As a matter of fact, although the orders were issued, the actual organization of the troops on the above schedule was not carried out, the work being done by such army troops and others who were available. The result in general was that there was no central organization of a Light Railway Department. What happened to the organization of Roads is told at length in connection with the road work in the following chapter.

Much is to be said in favor of both the principle of centralization and its converse when considered theoretically. The A. E. F. being composed of only two combatant armies, one of which carried on extensive military offensive operations, the second army being on the point of attacking when the Armistice was signed, it was not difficult to achieve good results with a segrega-

tion of authority. For several armies the centralization principle presents many attractive features, and by selecting men of judgment to act as Assistant Directors at Army Headquarters and by confiding to them ample authority for action at times of emergency, the British were able to avoid friction, secure harmony and produce coöperation, all of which is so essential to military success.

CHAPTER XXII

ROADS

Before they were damaged or destroyed by the direct action of war or suffered to fall into a state of bad repair, France could boast of roads that, in excellence of construction and systematic convenience in location, were not surpassed by the highways of any country in the world and that were equalled only by those of Germany. No matter where the traveller went, whether through the rich and populous districts or those but rarely visited, the highways, usually straight and marked with rows of tall and stately poplars, were a source of continuous joy. The surface was good, the ditches were well kept, little depressions were repaired before they reached the dignity of holes, and there was a generous supply of accurate direction signs and distance posts.

There are three classes of French highways, the "Routes Nationales," which are the main arteries built and maintained by the General Government; the "Routes Departmentales," the responsibility of the departments into which France is politically divided, and the local roads or "Routes Communales" within the limits of the communes or what would be called townships in America. These roads were all metalled, except for a few exceptions among the Routes Communales. In the vicinity of some of the large cities the Routes Nationales were paved with stone blocks to withstand the heavy concentrated vehicular traffic, but elsewhere all the roads may be said to have been constructed of a water-bound macadam with no oil or other coating and with widths and thicknesses that were governed by their comparative

importance. While no definite rules can be given, it may be said that the first two classes of roads have a six-inch surface laid on a solid foundation, well drained and with established limits of gradients and curves, while the communal roads have a lighter four-inch construction. By this system of definitely separated responsibility for the care of roads, there resulted a splendidly planned system of inter-city and inter-department highways that became excellently well adapted to the long-distance military traffic of war times.

The usual method of maintaining French roads in times of peace is to divide them into sections with one man called a " cantonnier " in charge of each. Piles of broken stone are delivered along the road with which the cantonnier repairs soft spots and small breaks as fast as they appear. He also sees to the drainage and the removal of excessive mud. In this way, a road is always kept in service. When finally the whole road needs a general overhauling it is done by large gangs of " entrepreneurs." Rock suitable for road construction abounds generally throughout France and the question of machinery and equipment for maintenance was not a serious problem, especially since the cantonnier was accustomed to break by hand the stone he needed.

The practical road-building problems confronting the engineers of the American Expeditionary Force were of two kinds — the more permanent repairs in the Zone of the Rear for the Service of Supplies and the hasty construction and reconstruction with improvised equipment and tools for the active army at the front. In the work in the forward area, the best engineering practice in permanent and economical road building was frequently of secondary importance to the maintaining of military communications. The latter consideration was so decidedly paramount as to justify a choice of materials and a character of temporary repairs that would ordi-

narily be condemned in civil practice. The successful officer on this duty was he who recognized that time was always the all-important element, at the sacrifice of all other considerations, and who successfully kept the traffic moving day and night.

The work in the Service of Supplies being removed from the actual front more nearly approximated normal conditions except that it was always executed under great pressure. The work in the army area reflecting the strenuous conditions of battle presented phases that are of greater technical interest.

The first requirement of a military road in France, and it admitted of no exception, was that there must be a special and hard-wearing surface. Under motor trucks carrying five and even more tons of ammunition, tractors hauling heavy guns, and an unbroken procession of all kinds of other vehicles, a dirt road would not only not withstand the wear even for a short while, but would be a deceiving trap leading traffic into an impasse. There were only two kinds of road surface used, stone and wood. To furnish the former, all available French quarries were called on, new ones were opened, and at frequent intervals to save transportation, while at times of emergency bricks and stones from the walls of ruined houses were taken and crushed.

It is interesting to trace the building of the A. E. F. road organization, beginning with the rather loose provision made early in 1918 for the care of certain important highways in the Service of Supplies, and carry it through the period of the establishment of the First, Second and Third Armies with their special requirements in their active areas. War Department Order 108, 1917, which provided for the organization of special engineer regiments, made provision for this branch of work. The Twenty-third Engineers was assigned to the important duty. Like the other regiments, the Twenty-

third was recruited of specialists from all parts of the United States, including among its enlisted personnel a very large number of technical college graduates, engineers chosen from the staffs of various state highway commissions, and contractors experienced in road and bridge building and quarry operation. The regiment was equipped with motor trucks, wagon train auxiliaries and special road tools. Arriving in France during the early part of 1918, during the dark days of the German offensive, they found the American forces facing the necessity of adapting themselves to the needs of the moment and of planning the work in advance, so far as engineering effort could do so, in conjunction with the French, as the date for the formation of the American army as an independent unit had not been fixed. Port facilities were being rushed, and the large supply depots were matters of such immediate importance on account of the increasing volume of troop arrivals that it became necessary to divide the Twenty-third Engineers and make use of the engineering ability of separate units on harbor, dock and water supply construction at the base ports, and on hospital, warehouse, railway and bridge building in the Service of Supplies, in addition to their attending to road construction and maintenance required by different American services in various parts of France.

During this period the charge of the roads for the Service of Supplies came under the Director of Construction and Forestry, operating through section engineers, and for the Zone of the Advance under the Director of Light Railways and Roads. Such organization generally existed until August, 1918, when the First Army, A. E. F., took over the highway work in its own army area. These section engineers and their staffs were usually officers of engineering organizations or casual officers appointed more or less permanently in charge of the

large engineering work in different localities, where road construction was an incident to the requirements of other construction.

There existed many differences of opinion as to the proper solution of road problems, with little effort made at that time toward the standardization of specifications and methods. Distribution of the scanty supply of road-building machinery and equipment was made many times without coördination of the requirements as a whole. The efforts on military roads were, practically speaking, concentrated in the immediate vicinities of large engineering projects. The section engineers had available only a constantly shifting body of troops for the work, the special road regiment being employed in other lines in many different localities.

In spite of these inevitable irregularities incident to the development of a great organization, the results that were obtained were remarkable and will make a proud chapter in the list of achievements of the American army engineer.

The actual work done was mainly the maintenance of the heavy traffic roads in re-surfacing and patching of holes as they developed, the stone being obtained from quarries operated by Americans and also through purchase from French sources. The obtaining of sufficient binder and screening material was frequently a serious problem, and repair gangs were forced to use sand and sometimes loam to hold the top course of the road together temporarily, the work being carried out at all times under full traffic. Equipment in the shape of rollers and crushers was purchased or leased from the French in order to eke out the scanty supply of American equipment on hand, and was worked frequently night as well as day.

The organization for the solving of road problems of the army was in a process of development even up to the

time of the Armistice. The necessary brigading of the American troops with the French and the British to stop the German offensive in the spring of 1918, was one obstacle to the prompt creation of an efficient road engineer organization. Troops which had been designed to be army troops and had been sent over in the spring of 1918 with equipment purchased specially for them, had not been immediately used as such. Consequently the men and tools were scattered throughout the various projects of the Service of Supplies.

In the short time during which the First and Second Armies, A. E. F., were in active operation as such, namely, from August 10, 1918, to the signing of the Armistice, there was not enough time to complete the segregation of the highway troops as planned. Therefore, the engineer officers of the army charged with the responsibility for the road work were forced to adopt temporary expedients in order to do the utmost possible in keeping the road building and repair work up to the fast and steadily increasing demand of the army.

Previous to the beginning of the St. Mihiel offensive, the forward dumps of road material were stocked through the agencies of both the light railways and roads. Such a division of authority seemed to be a logical one and serving the requirements of expedience in organization, the movement being controlled by an officer known as Engineer of Light Railways and Roads, reporting to the Chief Engineer of the Army. Later when the great importance of both of these arteries for the supply of the army became such as to render necessary the operation of the two as equally important functions of engineer troops, a further division of authority was adopted.

Under the Engineer of Light Railways and Roads of the First Army there were officers known as Corps Road Officers, to whom was given the direction of

road work in certain geographical areas corresponding roughly to those of army corps. To these officers were assigned engineer troops and labor battalions, as well as equipment and supplies both for work in hand and for that in contemplation to be required in following the advance of the army. These Corps Road Officers were charged with making such reconnaissance as might be necessary and within their areas were allowed practically the full control of such troops as might be assigned by the Engineer of Light Railways and Roads. Practically, however, they were officers detached in most instances from their own troops over whom they retained general administrative responsibility. On the other hand, engineer troops and other organizations were assigned to these same Corps Road Officers for work and not supervision. This situation could not work to the best possible advantage, but the general requirement of expediency must be borne in mind. The double responsibility of these officers in exercising an administrative command over their own troops while at the same time rendering the special services for which they had been detached, made it extremely difficult to accomplish results to the best advantage both for proper administration and constructive engineering work.

There were five Corps Road Officers appointed at the time of the St. Mihiel offensive, and to each of them were assigned companies of the motor and wagon train of the Twenty-third Engineers as well as service battalions. The separation of these troops from their own battalion commanders and administration orders undoubtedly worked a hardship on their efficient administration and led to results that bore evidence of individual efforts rather than unified efficient team action.

The great rapidity with which the objectives were reached in the St. Mihiel offensive made but a small call upon the road troops during the active advance. In the

consolidation of the new front, road work became a problem of repair rather than of construction. This problem was not serious, as the German engineers had kept the roads behind their front in excellent condition. But the work across No Man's Land required the filling of shell holes and complicated trench systems, and the removal of a number of very solidly constructed obstacles especially in connection with the German lines.

For two or three weeks prior to the greater American offensive of the Argonne-Meuse there was exceedingly intensive preparation. But during the attack and especially as it developed in intensity, the care of roads for the army was divided into three parts: first, the Division Engineers who undertook the necessary pioneer work from the front line as far back as the division authority extended, generally speaking to include the divisional light artillery positions. Behind the division troops and their responsibility for roads and bridges were the Corps Engineers, whose authority extended back to include the forward ammunition and supply dumps. The Army road engineers undertook the care of the more permanent army roads, which in general lay behind the forward dumps. The Road Department was one of the new departments where proper relations between division, corps and army troops were consistently maintained.

As may be imagined, the amount of road repair and construction increased the further the area became extended, due to the advancing front lines. Both divisional and corps troops were forced by the emergencies to adopt many expedients to accomplish the necessary road results in order to accommodate the rapidly changing tactical situation. The situation was further complicated by the different needs of the several divisions making up a corps front. Such differences demanded special routing of traffic and the maintaining of separate lines of communication. The divisional troops also were

changed and rested as their divisions were placed in line or withdrawn. The many problems of the individual division were considered as practically solved when the work had been brought to a point that furnished immediate relief, even if in a temporary manner only. The executing troops had meagre mechanical equipment and relied on ready-made methods and hand labor. As one illustration of similar character expedients used, canvas bags were provided in which men carried on their shoulders stone obtained from demolitions and ruins in the neighborhood, carts, horses or mechanical traction power being entirely lacking.

The degree of permanency in road work increased according as the work was handled by the corps and army troops until a point was reached where heavy equipment, such as crushers and road rollers, was employed.

As time went on the problems of light railways and roads became so great of themselves as to render the efficient active management of both by one officer practically impossible, and it became harder to coördinate the work of the assistant corps officers and the troops under their jurisdiction. About October 20th, a separation in the organization was effected, and the commanding officer with the staff of the Twenty-third Engineers, the army highway regiment, was withdrawn from work on the construction projects in the Service of Supplies, ordered to the First Army and appointed Engineer of Roads First Army, reporting directly to the Chief Engineer of the First Army. With this division of organization and with the greater number of the experienced road officers of this regiment available, corrections in the former organization were made to allow for the further expected extension of road responsibility in following up the offensive. Additional service troops were assigned, a definite system for maintenance and repair was organ-

ized, and liaison was established with corps engineers so that the rapidly increasing army needs for highways could be attended to more easily and quickly.

The advisability of this recognition of the vast importance of highways to an advancing army was well borne out in practice, especially in the time between the starting of the second phase of the Argonne-Meuse offensive, November 1, 1918, and the Armistice on November 11th. On this latter date nearly 800 kilometers of road were actively under supervision and repair by the technical troops of the Twenty-third Engineers, with their motor and wagon trains and a number of service battalions and pioneer infantry regiments assigned to them for labor. These army road troops under the jurisdiction of the Engineer of Roads, First Army, on November 11, 1918, amounted to some 21,000 men.

Little has been said in the above of the natural difficulties under which the work described was executed. The practically incessant rain was a factor which heavily taxed the efforts of the troops employed to keep the roads in passable condition, and further, was a great element in the rapid deterioration of the surface and foundation, strained as they were by the tremendous volume of truck and automobile traffic. This traffic, particularly in the army area, was necessarily confined to main arteries of communication supplying the three corps of the First Army front. The traffic census taken in Varennes showed more than 12,000 vehicles passing one point in twenty-four hours, so that the practical difficulties of making road repairs while the surface and shoulders of the road proper were rapidly deteriorating under the traffic, may be imagined. Coupled with these difficulties, the shelling of the back areas by the Germans became many times a disturbing factor to the morale of the troops employed, and it is a proud tribute to the perseverance, energy, ingenuity, and determination of the American engineer

troops on this work that, in spite of always increasing demands and working against the constant obstacles of weather, traffic and shelling, there was no instance in the army area where traffic was stopped due to a failure on the part of the engineer troops to have any road ready to bear its designed volume of traffic.

With the coming of the armistice, the road problems of the army engineers changed to those that contemplated a greater degree of permanency in both construction and maintenance. Shortly after the cessation of hostilities, all road work of the American Expeditionary Force in France was placed under the charge of the Director of Construction and Forestry. Road districts were established, and a system of patrolling, similar to the French peace-time " cantonnier " method, was introduced with engineer officers in charge of districts and with a better rearrangement of engineer troops and supplies. Serious difficulties were again encountered in the spring of 1919 at the time of the spring thaw, which again forced the road toops to work under high pressure in order to keep abreast of the traffic requirements.

In the area of occupation of the American Third Army, the control of road work was given to the Chief Engineer of the Third Army, who employed to a large extent local civilian labor maintaining the arteries of communication within the area.

Generally speaking, it may be said that the roads of France as used by the American Armies were left in a good state of rough repair, as an effort was made before the troops were withdrawn from France to put them in as satisfactory a condition as possible. But the wear caused by the intense and long continued war traffic calls for a complete resurfacing to restore the roads to the same state of excellence as existed before the war, in spite of all the energy and material that was expended in their repair. The great quantities of material

that will be needed for this perfect restoration, especially when all the other roads in France are considered whose condition is quite similar to those in the American sector, cannot possibly be available for even several years if the present output of the French quarries be taken as a basis for the supply. It is this work of permanent resurfacing which the French, with labor available after their own demobilization, are willingly taking up systematically as one part of their gigantic task in effacing the scars of the war.

It will be seen that the American road organization was in a continuous process of development up to the signing of the armistice and it had not reached the point where actual experience dictated precedents. In fact, no attempt was made to establish individual American precedents or standards, the officers realizing that it was far better to follow French practice. Therefore, to give examples of standards that were in principle common to the allied armies, recourse must be had to the experience of the French and British.

The width of the stoned surface of French roads was from three to five and a half meters. For military service it was found that there was needed for single-line traffic a width of at least three m., for double traffic six m. and for triple traffic eight m. To widen one kilometer of road from three m. to six m., 1,800 tons of stone were required calling for 1,800 days of labor in the quarrying, six light railway train loads for the transportation, 120 truck days and 2,400 labor days on the placing, in addition to a large amount of heavy equipment of road rollers, sprinklers and crushers.

In the construction of new or the reconstruction of old roads a strong foundation was absolutely necessary, otherwise the heavy artillery and trucks would soon break through. It was found that such a course of

large stones should be not less than ten inches thick. These stones were placed by hand, set on edge and diagonally across the road, or preferably like the letter V. The crevices were then filled with small stones and the whole rolled with a ten-ton roller. On this base an eight-inch layer of broken stone three inches in size was spread, sprinkled and rolled. On this a second layer of the same thickness but of smaller stone was placed. These two layers gave a compacted thickness of about twelve inches.

It was found desirable to keep the roads as flat as possible, as excessive " crown " caused skidding when the surface was wet, resulting in traffic jams. When an unbroken procession of vehicles can be measured in miles it is plain that anything tending to cause a jam must be avoided. The road engineers learned that it was much more economical to maintain drainage by scraping than to pick up overturned trucks, because when once a truck on a busy highway had slipped into a ditch, the only thing to do was to overturn it. To this same end it was found desirable to have some sort of a curb to prevent wheels from leaving the stoned surface when they would either break the shoulders or dig into the soft earth and become stalled. Piles of broken stone to be used in repairs well answered the purpose. In all such matters hasty expedients and makeshifts were the rule, while the following of standard plans was the exception, the engineers on the ground having great opportunity for the exercise of individual judgment.

The alternate material for road surface was plank, a method of road construction very popular with the British. Such roads were laid on six rows of stringers, if for a single line of traffic, with a plank decking three inches thick if of hard, and five inches if of soft wood. Spikes were used which could be driven, but if work were done near the enemy's lines, holes were bored in advance to reduce the noise of hammering.

The great advantages of plank roads were the speed with which they could be laid and the possibility of constructing them when stone roads could not be built, as for instance, across a country covered with shell holes, where the filling deposited in the latter would have required much time to become sufficiently consolidated to provide a foundation. As for speed, the British in front of Cambrai built a double-way plank road two and one-half miles long in ten days, and the French estimate was that sixty men could lay one-quarter mile of road four meters wide in ten hours. Plank roads would not answer on gradients steeper than ten per cent, and even on rates much less than that, a coating of gravel was found to be very helpful. In wet or soft ground the French used bundles of fascines laid diagonally, staked and wired down to give a firmer bearing for the plank surface to rest on. Such roads were very expensive and temporary in character, although they would last for several weeks. But the rapidity with which they could be built rendered them most valuable when speed, as during a drive, was all important.

The maintenance of roads during war depends on repairs, but also on care during the thaws and on rigid control of traffic. The first may be dismissed from consideration here as repairing of roads under war conditions, even in the Zone of the Advance, presented few features out of the ordinary except in the matter of temporary expedients as explained, but the second is of the highest importance. Next to the wear caused by the heavy traffic, the greatest destructive agency was alternate thawing and freezing. So long as roads were tightly frozen there was no trouble, but when the included ice expanded during the act of thawing, the road surface was "heaved" and the bond between the stones loosened. In such condition the passage, especially at high speed,

of a few heavy motor vehicles would destroy large areas and call for extensive repairs. To obviate this or to reduce the resulting damage to the minimum, both the French and British road authorities enforced strict traffic regulations during periods of thaw. At such times the French closed the principal roads against automobile trucks, loaded wagons in convoy, and loaded wagons isolated when hitched to more than one horse for a two-wheeled cart, and to more than two horses for a four-wheeled wagon. Light passenger automobiles were restricted to a speed of ten miles an hour and horse-drawn vehicles not otherwise barred were held to a walk.

The British regulations provided for the prior storing at advanced posts of sufficient supplies to permit the closing of roads against all but emergency traffic for five days, and the placing of road repair material in piles at the road sides. Immediately a thaw began or was known to be imminent, telegraphic orders were sent out putting thaw precautions into effect. These called for, first, the elimination of all unnecessary traffic of every kind, and the limiting of emergency traffic to speeds of eight, ten and fifteen miles per hour for trucks, ambulances, and light passenger cars respectively, the emergency in each case being indicated by a special pass. The repair gangs then removed all slush and mud from the surface and repaired all soft spots as fast as they appeared.

Traffic control as in a city's streets was an absolute necessity. When the number of vehicles on a highway reached the enormous total of 17,000 in a day, which means that a vehicle of some sort passed every five seconds throughout the whole twenty-four hours, it is obvious that unless traffic rules were intelligently worked out and strictly enforced, circulation would be superseded by a hopeless tangle, especially as it must be kept in mind that at night near the front all lights were forbidden and

traffic had to be handled in darkness. If such a number of vehicles were exceptional, figures closely approximating it were of frequent occurrence during periods of stress. The regulations provided in general that a military policeman, whose orders were supreme, was stationed at all road intersections where traffic routes crossed or joined, and that unless otherwise specially permitted, vehicles must keep in single file; that convoys were to leave spaces every tenth vehicle to allow ambulances and high-speed official cars to cut in and so pass ahead, and that a disabled vehicle must be at once drawn aside, or overturned if necessary.

The volume of material required for the construction and up-keep of roads was tremendous. American experience showed that a minimum of 5,000 tons of stone per day per army area would be needed. A typical French army consisting of 250,000 men used during a period of eighteen months no less than 2,000,000 tons of stone, or an average of 3,700 tons per day during the whole time on approximately 1,000 kilometers of roads within the army area. The British transportation figures in France, after the army and consequently freight shipments had become established on a regular basis, show that railway material accounted for 32 per cent of the tonnage, and road material for 22.5 per cent, while the weight of ammunition, ordnance and general supplies, the last including food, did not when put together, amount to as much as that of road material alone.

The labor of maintaining the roads was exceedingly severe. In the French and British armies, men who had been wounded, and although recovered, were incapacitated for the more active but the not more strenuous work in the trenches, were assigned to road service. Had the war continued sufficiently long for a similar body of men to have been collected in the American Army analogous action would probably have followed. An excel-

lent picture of the human side of road repair work is given in the following verses by an English officer, whose name a diligent search has failed to reveal:

CORP'L GILES

We's working 'pon the Blankcourt Roads wi' shovel an' wi' pick;
An' Corp'l Giles from Hatherleigh directing wi' his stick,
'Tes one long line o' traffic up, another long line down;
'Busses an' carts, for all the world like streets in London town,
Horses an' marchin' infantry an' batteries o' guns,
Goin' up to teach good manners to them nasty-minded 'Uns;
Lorries an' wains an' moty-cars, for miles an' miles an' miles."
"'Tes like a year o' market-days," says I to Corp'l Giles.

We makes the roads an' mends the roads, an' makes them all again,
The traffic tears 'em all abroad, wi' one good shower o' rain.
We scrapes off mud an' strows our stone beneath the grinding wheels.
The sweat runs down behind our ears, we'm muck from caps to heels.
We'm deaf, an' halt, an' some's half blind, an' Corp'l Giles he's lame,
The smart young gunners laughs at us, which seems to me a shame.
"But, Lord, who minds 'em laughing? If 'twarn't for such as we,
How would 'em get their guns to front?" says Corp'l Giles to me.

They goes up sweatin' in the sun, or singin' through the rain,
An' when they change Divisions some comes singin' back again.
An' some stays where the wooden crosses mark the last advance,
(There's lines o' little crosses all acrost the North o' France.)
An' past the singin' muddy boys the Red Cross motors go,
Packed full o' quiet bandaged forms, an' rollin' very slow.
It makes 'ee sad. . . . "An' yet you knows, if warn't for such as we,
The wounded wouldn't ride so smooth," says Corp'l Giles to me.

CHAPTER XXIII

TRENCHES AND TRENCH WARFARE

The winter of 1917-1918 was not a trying one. Severe cold set in early in December and continued unbroken until the middle of January with considerable snow. Then it moderated slowly and evenly so that the frost, as it came out of the ground, did but little damage to the roads. After the 1st of February the weather and the physical features of roads and country presented as pretty conditions for fighting as anyone could desire. In other years February had always ushered in the spring campaign with a movement by one side or the other, or by both. But the situation of 1918 was quite different from that of other years. The fighting during the previous autumn, culminating with the double battle of Cambrai, had shown that a practical deadlock existed. While local gains had been made during the year, they led to no real advantage, certainly not when cost was counted.

The opposing forces viewed the deadlock through very different spectacles. The Anglo-French allies knew that an army had already begun to arrive from the west across the sea and that soon there would be at their sides a force giving them a great preponderance of numbers. They could afford to wait. The enemy saw the same thing but with emotions of another kind. The German high command, no matter what they might give out to the effect that Americans in number were not in France, that none could pass the line of submarines, and that if any did arrive they were not trained to fight, knew well that a real army was coming and that if victory were to

be gained the allies must be beaten before summer, otherwise all was lost. Along the front the quietness was broken only by an occasional shell fired apparently without object, by some small raids with no other intent than to gain information as to what enemy forces were holding the opposing line.

The enemy situation was critical and only desperate means could save it, because time, the only antagonist against which man cannot compete, was running against him. It was generally recognized in the allied ranks that the enemy could and undoubtedly would deliver a great smashing blow in which all his strength would be concentrated in the hope of overcoming the allies by one supreme effort, a sort of gambler's stake where all is risked to win all. There was nothing else for him to do. On the allies' side all were waiting for the blow to fall. Where and when would it fall?

Field Marshal Sir Douglas Haig stated that he had every reason to believe that from apparent German concentration the attack would be delivered somewhere south of the Sensee River. On March 19th he learned that it would be launched on the next or second day on the Arras-St. Quentin front.

At that time there were but three American units in the northern sector, all engineers, the Twelfth and Fourteenth Regiments and a battalion of the Sixth Engineers. The first two were occupied on forward light railways, with headquarters of the Twelfth Regiment west of St. Quentin, and those of the Fourteenth southeast of Arras, while the Sixth Engineers were building some bridges near Peronne.

Before dawn on March 21st, a date that will always be one of the milestones that mark epochs on history's road, an intense bombardment of the whole front from the river Oise to the river Scarpe began and continued for five hours, during which shells filled with high explo-

sives and the deadliest of gases were mixed promiscuously, forcing the engineers working the trains to wear masks. It was evident that the Germans intended to attack the Fifth Army, B. E. F., with an overwhelming force. This army was on the extreme British right and was, therefore, next to the French left. The enemy apparently hoped to find a weak plane of cleavage in the line of junction of the two nations. The Germans had concentrated more men on this part of the front than there were in the entire British army in France (Field Marshal Haig's report). The attacking party always has the advantage. Knowing where he intends to attack he can bring to bear such forces as he desires. The party on the defensive must be prepared to parry a blow to be delivered at any point and cannot move up his reserves, not only until the attack has begun but after he is certain that the attack in question is the real offensive and not a mere feint. Five hours after the bombardment began the enemy infantry attacked in great force on a front of fifty-four miles.

It is not the province of this book to describe this battle which, had it succeeded, would have cut the British army from contact with the French, would have severed the lines of transportation running north and south and would have given the Germans access to the Channel. In that event the war would probably have been brought to a disastrous conclusion before American participation had become sensible. The story of the offensive is well known in general terms. When all the facts on both sides are finally obtained, it will provide material for military debates and arguments for many years. This book is concerned only with the engineers.

At 5:30 P. M. on the 21st the commanding officer of the Twelfth Engineers received orders to withdraw from his advanced headquarters at Montigny to Le Mesnil, running back the equipment on the light railways. Most of the rolling stock was saved, but the shelling was so

severe that some vehicles were intentionally destroyed before being abandoned. On the 22d, regimental headquarters were again moved, this time to Fay. At 3 P. M., March 24th, orders were received to abandon Fay at once and to destroy all rolling stock. Outlying detachments of the regiment had a similar experience, falling back stage by stage through the four days, March 21-24, running the little engines and cars over such lines as were open until the rear ends of the light railway system were reached, when trains could be run no further. Then, but not till then, all locomotives and cars were destroyed to prevent their capture. The regiment having lost its regular assignment through the light railways having passed to enemy hands, was detailed to assist in constructing the trenches along a line running near Villers-Bretonneux, east of Amiens, a position that the British high command had decided to fortify and hold.

The experience of the Fourteenth Engineers was similar. During the twenty-first they were engaged in hauling ammunition to the forward batteries and repairing the lines as fast as they were cut by shell fire. On the following day they, too, were obliged to commence a retreat, carrying with them their rolling stock, with which they succeeded in salving much ammunition, something very precious at such a time.

The Sixth Engineers had their turn on March 26th. After a continuous rear-guard action of the greatest intensity it was but natural that the orderly arrangement of the line should have been considerably disturbed. Late on the 25th, General Grant, Chief Engineer of the Fifth Army, B. E. F., learned that a gap was being created by the line drawing apart under the enemy pressure, a gap that must be stopped or disaster might follow. He seized the Sixth Engineers, various scattered detachments of all arms, and even stragglers who had become separated from their units, and amalgamating them into a brigade he threw it into the widening gap. Then he

turned the command over to Brigadiēr-General Carey. This scratch brigade, known as "Carey's Army," though suffering severe casualties, held their position in front of Amiens for some days until relieved, by which time the new British position had been made reasonably secure.

It was now evident to the British high command that the expected great offensive had begun, and that the enemy would make a continued effort supported by the full force at his disposal to reach the channel ports. A review of the field showed that the advance already made by the enemy had overrun many lines of defense, calling, therefore, for extended supplemental defenses as well as developing into works of a more permanent and better equipped character those that had been hastily constructed. It was still an engineer's war. While the army in the north was being reinforced by all available British and French reserves to prevent the onrushing enemy from reaching Amiens, Field Marshal Haig wired the American General Headquarters for two regiments of engineers. The Eleventh and Fifteenth were at once designated to join their comrades in the valleys of the Somme and Lys, the former to strengthen the defenses in the neighborhood of Arras and Bethune, the latter to construct new lines of communication replacing the transportation facilities that had been lost.

A ditch with the excavated earth forming a parapet has constituted one of the simplest and most easily made defenses, since the time when men began to be armed with guns. In the American war between the States, the construction and systematic utilization of trenches underwent great development and the elaborate trenches in front of Petersburg, resulting in a deadlock for many months, are famous. The Turkish-Russian and the Russian-Japanese wars saw trenches used on a still larger scale, but the late war carried them, both in general extent and in complete details of construction, far

and away beyond any previously conceived possible limit.

From and after the battle of the Marne in September, 1914, to the beginning of the final offensive in September, 1918, both sides faced each other from line upon line of earth trenches with a total length that has never been measured. These trenches extending over a front of about 450 miles can be estimated, without doubt, in terms of tens of thousands of miles.

The general principles of trench warfare and trench construction were the same in the Allied and German armies, but details differed radically and to a large extent according to national idiosyncrasies. In systematic layout, in thoroughness of construction, and in elaborateness of design the Germans excelled all the others. The sides of their trenches were strengthened by posts and at times reinforced with concrete. There were steel shields to protect snipers, and concrete structures, or "pill boxes," for machine guns. Row upon row of trenches were dug with acres of wire entanglements, many of which were never used, but were constructed so as to be ready for use if needed, while dugouts existed of great capacity and most elaborate construction.

Some of these dugouts, especially those for field headquarters, were really works of art, if anything, whose appearance resembles a rathskellar, can be said to partake of the nature of art. They were panelled with wood, furnished with rustic tables and chairs, lit by electric lights and, as German officers, especially of high rank, seemed to be particularly anxious as to their personal safety, they were made very deep with plenty of earth cover and had steel doors to protect the entrances against shell splinters.

The German trench system was really a connected chain of redoubts or field forts. As part of such a chain they skillfully utilized the ruins of villages whenever the latter were situated so that they might be used. Thus the

streets of a village on the front line would be so arranged as to constitute a series of culs-de-sac with no outlet at the far end, so that in the event of their being rushed the entering troops could not advance. Nor could they move laterally because the doors and windows, or what remained of doors and windows, were heavily wired. Troops once in such a street would be exposed to a galling fire from the buildings without the possibility of attacking the defenders. As the cellars of these houses were connected with the trenches by tunnels or underground passages, they offered extraordinary facilities for defense. It was said that the German soldier, trained to be a part of a great machine where personal initiative was discouraged, could not be depended on for stout resistance unless he felt assured that he had the best means of protective defense.

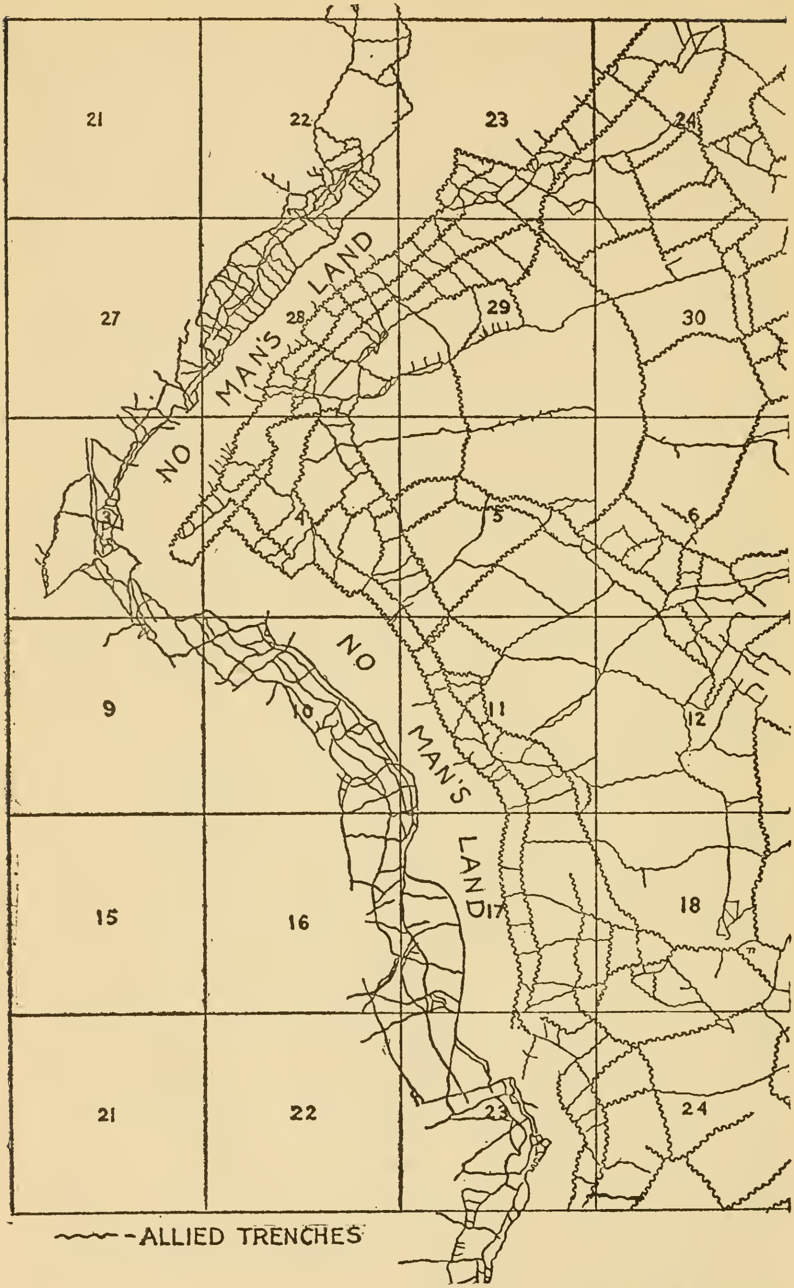
Opposed to this was the French theory, that an army acting always on the defensive can never win. To the offense and not to the defense comes victory. A soldier should, therefore, be given all necessary protection, but he must not be encouraged to rely on that protection nor to feel that any position he occupies is anything more than temporary. The French trenches were, compared with the Germans, much smaller, far less comfortable, and less permanent in character.

The British trenches were between these extremes in design and execution. They were usually better built than the French, deeper and wider, with parapets and firing steps more systematically laid out and with rather better headquarters arrangements. They fell far short of the elaborate German standard and so did not develop or yield to the natural human propensity toward a fondness for permanent security. The British held that it was unwise and unnecessary to permit men to place an undue reliance on the strength of their defenses. If any criticism of the British system of defense will lie,

it was that they depended too much on a system of front-line trenches and did not provide enough reserve positions on other lines in the rear capable of being held should the first defenses be carried. The argument against such provision was that men when hard pressed would be more inclined to fall back if they knew that there was a position in the rear ready for occupancy.

This is an interesting point in psychology, a science that should not be overlooked in its application to the successful conduct of war. To be able to form a correct estimate of the mental workings of masses of men under war conditions is one of the most valuable faculties that a general can possess. Perhaps it is not too much to say that unless he can do so, no matter what his military ability, he cannot be a great leader of men. The British trench system was in general accepted by the American Expeditionary Force as the best standard to follow, except that General Pershing went even further than the Allies in dislike to permanent positions. He believed that the war must be won in the open and, perhaps, at no distant day. He was, therefore, opposed to American troops becoming accustomed to trench warfare.

A map of trench positions shows in most striking manner the difference between allied and enemy methods. While the allied defenses consisted frequently of but three lines and rarely more than six, the German trenches were numbered by the dozens and extended back from the Front trench to a distance of several thousand yards, rows of trenches and wire entanglements. They were enabled to construct these labyrinths by drawing on the French and Belgian civil population for assisting labor. There is no question that they placed unwarranted confidence in these constructions, and their morale was undoubtedly shaken when they found that their positions in spite of all the labor and skill expended on their creation, were pregnable. Once they were



MAP SHOWING COMPARATIVE EXTENT

of German and Allied Trenches.

driven out, they never succeeded in making a stand in the open. See the map of opposing trenches on pp. 322-3.

As trenches actually existed in the field it would have been very difficult for an observer to have recognized any system or underlying scientific theory in their general layout. Time and the vicissitudes of battle tended to efface the marks of orderly arrangement. Some parts of a system might be destroyed by a concentrated bombardment, be captured or be abandoned as not located to the best advantage, or some "switch" or additions might be constructed, any one of which steps would alter the design of the original plan. Nevertheless there were certain general principles which governed the laying out of trenches, and the closer they were adhered to, the better was the defense offered.

A trench is primarily a construction intended to afford protection to troops holding the front line. It may be dug like a ditch wholly beneath the surface of the ground, or it may be between raised ramparts, as was done in the low lands of Flanders. But, of whatever form, it was still a trench in a military sense. As all the troops assigned at any one time to front-line service could not occupy a single trench, nor was it desirable that they should be huddled together, other trenches for their accommodation and for additional lines of defense had to be constructed. Since such additional trenches were a part of the front-line defense, they had to be cross-connected so that troops might pass freely from one part to another and without exposure.

In general, a trench system consisted of at least three lines of trenches substantially parallel, called the Front, Support and Reserve.

The Front or Firing trench was the main line of defense and consequently was prepared for offense. If possible, it was so located as not to be so close to the enemy's front line as to permit its being bombarded by

trench mortars, nor so far away as not to command (in a military sense) the intervening space. But this distance was one determined largely by local circumstances among which the enemy's wish was one very important item. In actuality the distance varied from fifty yards to one mile. While the Front trench was continuous it was never straight, as the engineer in laying out trenches abhorred a straight line quite as much as nature is reputed to do.

The ideal location for a defensive position was on the slope of a hill, in which case the Front trench followed as closely as possible the military crest. Perhaps if the technical reader will grant pardon, it may be convenient to recall to the non-technical reader the difference between the military and topographical crests. The latter is the top of the hill. But as the slopes of any hill are convex, it is rarely found that from the actual hilltop all points on the slope can be seen, and it is usual that this can be done only along some line on the slope itself, perhaps at a considerable distance below the top. That line, giving " command " or " sight " of all points below it, is called the military crest, and is the one with which an engineer engaged in fortifying problems is most concerned.

Below the military crest there are no " dead spots " in its immediate vicinity; that is, spots due to small local variations in the surface, that cannot be seen from it. Dead spots, not being exposed to sight and consequently direct rifle fire, furnish excellent places for attacking troops to pause, whence by a short rush they can reach the enemy's position. The ideal location for the Front trench is along the military crest, but in practice this is not always feasible at all points. If it be found impossible either by advancing or withdrawing the location to avoid a dead spot, adjacent sections must be so located so as to give a cross fire sweeping the spot that

is dead when viewed directly from the front. When "siting," as locating is technically known, was being done for new trenches and provided there was time to make a careful study, dead spots could be determined only by the siting engineer lying down on the ground and putting his eyes in the same plane that the eyes of the defenders would be in, when the latter came to occupy the trench

Behind the Front trench and preferably distant from it 80 to 200 yards lay the Support trench. If possible it was sited just below the topographical crest, but not so close to it that men's heads showing above the trench parapet would be silhouetted against the sky. The Support trench, as its name indicates, held the troops assigned to support those in the firing line. The troops in support are ready to go forward to the assistance of any part of the Front line in danger, while the Support trench itself was prepared to receive the defenders of the Front line if they were compelled to withdraw. If the two trenches were sited according to system, on sloping ground, the Support being higher than the Front, the former was a position with command over the Front line, and from it an annoying fire could be directed on the Front trench should the enemy ever secure a lodgment there. These two trenches were, therefore, closely linked and inter-dependent members of a single fortification.

The third or Reserve trench lay well behind the Support, not less than 200 yards nor, as a rule, more than 500 yards, though at times the nature of the ground required the latter distance to be exceeded. It was preferred that the Reserve trench be located on the reverse slope of the hill, that is, on the slope opposite from the other trenches or, in other words, over the top of the hill. The Reserve trench was, therefore, not exposed to direct fire, it could not be reached by any shells or bullets aimed

at either of the other two, and so was well adapted to house and shelter the reserves. It became a fighting trench only in the event of the Front and Support trenches being carried, when the troops holding the Reserve could fire on the attacking column as it came over the crest of the hill and presented a fine target against the light background of the sky.

In this case the term " reserve," as applied to troops, must not be misunderstood. When a unit was ordered into the line, it went there, under ordinary routine of stabilized trench warfare, for a definite number of days during which time its men would be distributed in rotation between the three trenches, those in the Reserve usually acting as carriers for supplies and ammunition to the troops in the Front and Support lines. When the period of service expired, the unit would be withdrawn to the rear for a period of " rest," as work in the rear was euphemistically called. During times of great activity, such as offensives or defensives, these regular schedules were, of course, forgotten. While a unit was in the line the men composing it took their place in the three trenches in turn.

The three trenches were connected by frequent Communication trenches to provide passageways between them, through which men could pass without being observed by the enemy. There was no rule as to how close together these Communication trenches should be. That depended on the nature of the ground, on the importance of the position and the number of men holding it. They were usually set apart about 100 to 200 yards when between the Front and Support trenches, and from 200 to 500 yards between the Support and Reserve. If the Reserve was on the reverse slope of a hill and, therefore, out of sight, troops could enter and leave it in the open. If it was exposed to direct vision, Communication or Entry trenches leading to it had to be dug back to

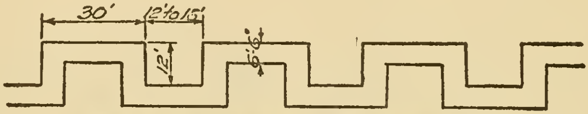
points where concealment was obtained, because the moment of relief was always an anxious one. If the enemy could learn the hour of relief they were sure to do shelling with serious effect, as the trenches would then be filled with twice the normal number of men, one unit arriving, the other departing, and probably both units weighted with their kits.

In front of the Front trench there were frequently outposts and nearly always machine gun posts, positions consisting of small detached trenches or shell holes improvised for occupation. Here small parties remained, unable to move in daylight but ready to repel an attack.

The Communication trenches were usually not laid out at right angles to the trenches that they connected, but preferably at an angle of about forty-five degrees, which prevented their being enfiladed by direct fire. They were also usable as firing trenches in case any part of the trench in front should be entered by the enemy. In such cases they became temporary or permanent "switches," that is, alternate sections for the kind of trench next in front. If a position was held for a long time, additions to the trenches were made for the above and other reasons, so that instead of three lines there might be many more in close proximity. The Germans were particularly fond of multiplying lines, and such multiplication undoubtedly strengthened the powers of resistance of a position.

In plan, or "trace," trenches were of four types: "Traversed," "Bastioned" or "Octagonal," "Zigzag" and "Wavy." There was one thing they must not be, and that was straight, because a straight line would never adjust itself to the undulations of ground. If it did so for any considerable distance, the enemy, by taking position at one end or at a distance in the direction of its length, could sweep it with an enfilading fire. Even if it were impossible to enfilade a straight trench,

a shell falling in it would certainly scatter its fragments to considerable distances right and left, causing many casualties. The trace must, therefore, be of such plan as to fit the ground and must have bends, or splinter-proof barriers, dividing it into short lengths.



TRAVERSED TRENCH

Fig. 5.

The Traversed trench was the one most used at first, perhaps because in plan it retained some of the old characteristics of permanent fortifications, and the human mind is loath to depart from old forms and familiar outlines. It was one for which the French exhibited great fondness, even to the end. As will be seen from the annexed Fig. 5, it consisted of a number of right angled turns caused by leaving undisturbed masses of earth projecting backwards from the front face. The traverses built at first were about eight to ten feet thick, but against concentrated modern shell fire that thickness was much too small, as such small traverses were quickly blown away and failed to give lateral protection. They should not be less than twelve, and preferably at least sixteen feet thick, separated by bays about thirty feet long. They were made twelve feet deep so as to lap or cover the traverses projecting forward from the back. It will be seen that these traverses cut a trench into a series of isolated though connected compartments, along which it was impossible to see from one compartment to the next.

The story is told of an Irish battalion holding such a trench. During a critical quarter of an hour and just

after a shell had exploded, a man in one bay called to a companion on the other side of the intervening traverse, "Are you there, Mike?" "Sure," came back the cheerful answer. A few minutes later another vicious shell exploded and with it again, "Are you still there, Mike?" When this happened a third time, Mike became a little irritated, and inquired somewhat petulantly as to the cause of the unwonted interest in his welfare. "I'm not meaning any harm, Mike, me boy," came the apology, "but we have a little pool here as to who'll be the next man hit, and I've drawn you."

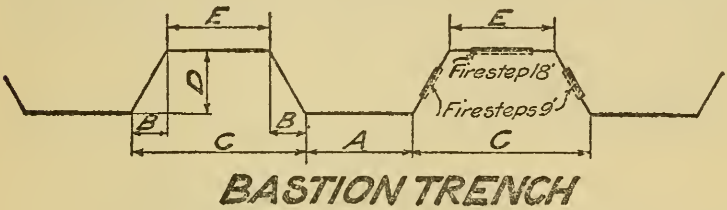


FIG. 6.

The Traverse type was very wasteful of space and time, especially after the necessity for wide traverses became apparent. A large part of the fighting front was necessarily sacrificed, the trace was awkward to fit to undulating ground, the right-angled turns increased the distance and consequently retarded progress through the trench, and it demanded the maximum amount of labor to construct. Its advantage was good protection against enfilading fire and shell fragments.

These objections were obviated or greatly modified in the Bastion or Octagonal layout, where any face can become a firing face, and in addition, the faces on the side can deliver a cross fire, an advantage not possible with the Traverse type. The standard dimensions of American and British practice with trenches of this character are given in the following table:

BASTION OR OCTAGONAL TRENCH

DIMENSIONS	AMERICAN STANDARD	BRITISH STANDARD
A	30 feet	10 yards
B	12 feet-6 inches	3½ yards
C	50 feet	17 yards
D	12 feet-6 inches	6 yards
E	25 feet	10 yards
corner angles	135°	120°

The next type, the "Zig-zag," was a modification of the above, where all angles were the same, and all sides were of equal length. This type of trench was very easy

Fig. 7.

both to lay out and to construct. As to laying out, all that was necessary for the siting engineer to do was to mark the angles, and the engineer troops following him would cut lines connecting the angle points and begin digging. In American practice the distance between entrant angles was eighty feet, as compared with fifty-one feet, in the British, while the depth was the same, fifteen feet. The shorter British length and consequently more acute angles, gave better protection against bursting shells or enfilading fire. It must be kept in mind that all these dimensions were suggestive only, to be adhered to only as far as the nature of ground permitted. In order to follow a given contour or the irregularities of the surface the engineer when siting had to make many modifications of dimensions.

From the Zig-zag it was an easy transition to the trench where the angles were rounded, giving a succession of curves instead of broken lines. This type of trench was named the " Wavy " trace, and is shown in

FIG. 8.

the diagram above, the dimensions being the same as its prototype the Zig-zag, the American standard giving longer sweeps than the British. The Wavy trench possessed many advantages which were so striking as to make it the superior of all unless there were special local reasons to the contrary, among which advantages may be mentioned:

1 — Ease and rapidity in construction.
2 — Great facility in passing through it, hence especially advantageous for communication trenches.
3 — Could be used as a fire trench at any point.

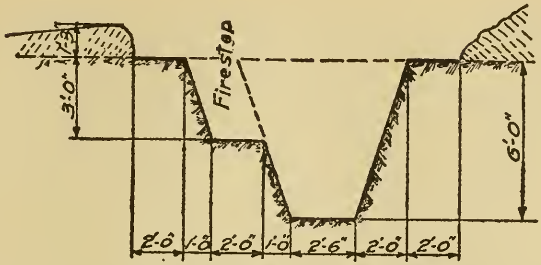
The disadvantage was that most men preferred a straight and not a curved edge to fire over.

In details and dimensions of cross-section, the trenches underwent some modification as the result of experience during the war. The early trenches were made both too shallow and too narrow. It was found that they should be sufficiently deep that men's heads would be below the level of the ground so that men need not rely on the covering presented by the parapet formed by the excavated material as giving any real protection. A narrow trench affords a little more protection against flying shell fragments, but this benefit is more than offset by the inconvenience to men passing through, by the difficulty of handling stretchers and by the certainty that a fall of the bank following a direct shell hit will completely block

it. Such were the results of British experience, which led to standards whose dimensions were even somewhat more generous than our own.

For a good substantial trench the depth of the bottom below the surface was placed at six feet, the width of the excavation at the top at six feet six inches, and at the bottom two feet six inches, so that the sides had a slope of two feet in six feet, or three on one. This cross-section or profile, to use the technical expression, was the minimum for any trench whether used for firing or communication. Such parts as were to be used for firing were widened on the exposed side by excavating a bench or "fire step" three feet below the top and two feet wide, so that at such places the top width became eight feet six inches. The fire steps were not continuous, nor did they occur in every bay even in the Front trench. It was not advisable to make any one step more than eighteen feet long, so as to avoid the temptation for men to congregate, which longer steps invited, and so expose themselves to simultaneous casualties. If fifty or sixty per cent of the whole length of even the Front trench was provided with fire steps, it was usually sufficient, while of the Support trench not more than forty to fifty per cent was made available for firing, with still less in the Reserve.

The excavated earth was thrown both in front and behind the trench and kept back from the edge about one foot six inches to two feet. The earth in front, the parapet, was leveled off to a gentle slope so that men could place their rifles on it. If the edge toward the trench was left one foot six inches high, a man standing on the fire step could rest his elbows on the original surface and, with his rifle lying on the parapet, fire comfortably. The excavated earth in the rear, the parados, was left irregular so as to prevent the head of a man looking over the parapet from being clearly outlined.



CROSS SECTION OF TRENCH
(With Firestep)

FIG. 9.

In the front face of the trench there were excavated receptacles for surplus ammunition and hand grenades. Covered lookout posts were established at intervals, where sentries could stand and watch over No Man's Land, looking through slits between sand bags.

In France the subsoil is usually a clay or chalk and consequently resistant against slips or falls. As a general thing, therefore, and very fortunately, the sides of the trenches were self-sustaining and remained so for months, even when exposed to the weather. When soft material was encountered, or a direct hit was scored on the trench involving placing of the sides, support for the soft earth was obtained by driving stakes into the bottom. Sometimes the stakes alone would be sufficient, but if not, hurdles made of brush were placed against the bank behind the stakes or the banks were covered with closely woven chicken wire. If the ground were very soft and the bottom hard, into which stakes could not be driven, a braced frame was designed, the long vertical legs on the sides acting as the bank's support.

The great enemy of trenches, or rather the great enemy of the men in the trenches, was water. The difficulties of disposing of it being accentuated by the impervious character of the subsoil. If trenches were

constructed on a sloping hillside, drains could sometimes be dug to the front, permitting the accumulated water to run away. But as the trenches were six feet deep, it was not always possible to get ground with a sufficient fall by which the water could be naturally drained off through any reasonable length of ditch. Then again a ditch, after it had been put into use through hours of labor, might be blocked by a single shell. Where natural drainage could not be had, pumps were installed which had to be worked by hand. Even at the best they were very unsatisfactory.

Stories have been told of the mud in the trenches which unfortunately are not exaggerations. Material falling into the trench from the banks, loose earth blown into the trenches by shells would, when tramped under constantly passing feet, become thoroughly broken up and finally, unless the drainage were exceptionally good, take the consistency of a thick brown soup. Long stretches of trenches after a spell of wet weather would have this fluid mud actually thigh high on the men. An effort was made to reduce the inconvenience by flooring the bottom of the trenches with "duck boards," a foot-walk consisting of two longitudinal stringers about one and one-half inches wide by three inches deep, on which were nailed light cross slats. These duck boards were made and consumed in enormous quantities for use in camps as well as trenches. They were the one redeeming element that under some conditions made living possible. An eminent American medical authority when asked his opinion as to what was the greatest medical achievement in the war, replied unhesitatingly the "Duck Board," as it had saved more lives than any other discovery.

The near presence of ground water to the surface in some localities, especially in the plains of Flanders, prevented the digging of trenches. If it were possible to dig part of a trench it was dug to such depth as could

be obtained, and then above the surface of the ground there was erected a rampart, the inside face of which consisted of stout stakes driven into the ground, supporting brush hurdles, the tops of the stakes being held, from turning over, by wires leading to anchor posts in front. Earth was then piled up on the outside against the hurdles to a thickness of six feet at the top, with an exterior slope of one on two. The trace of such a trench was usually of the Bastion form. In order to protect the men from shells falling behind them, a similar embankment was constructed in the rear, thus giving a trench profile of the same dimensions as the standard trench. Firing steps were constructed upon such bays as were selected for that purpose. The combined height of trench and rampart was the same as the standard depth of trench.

Forests were always used by both sides as points for defense. The only objection to organizing forests for this purpose was that the enemy would, probably, if the location of the defense works were known, saturate the locality with gas. Gas in a thick forest, especially if it were mustard gas, would remain for days before final evaporation. Details of trenches in forests did not differ from those constructed in the open except that they were usually reinforced more generously with machine gun posts and other isolated points of defense, called strong points.

Among the trees, avenues were cut, whence all underbrush and small trees were removed. These avenues were laid out radiating from various strong points, so that an attacking force passing through the forest would be subjected to crossfire from several points. Whenever trenches and outposts were constructed in woods, the big trees were left so far as possible, so as to hide from airplane observation the traces of either the outposts or the cross avenues.

The Communication trenches resembled the other trenches both in trace and profile, and were provided with fire steps on some bays so that they could be used, if so needed, as fire trenches. Inasmuch as they were intended primarily for passages, they were given the Zig-zag or Wavy trace, as that trace obstructed as little as possible the movement of men. The upper ends of Communication trenches were made straight for about fifty yards, whence a diverted connection was made with the Main trench, Support or Reserve. At the end of the straight stretch there was a fire step on the Main trench, with a parapet so constructed as to permit an enfilading fire of the Communication trench to be directed from it. This was done so that, in the event of the trench in front being carried by the enemy, the next line of trench could not be approached through the Communication trenches. Not more than two men at a time could advance through such a trench abreast, and certainly one or two men with rifles could easily defend it. The distance of fifty yards for the straight stretch was deemed sufficient to prevent the defenders from being reached by hand-thrown grenades, the much dreaded weapon in close fighting.

In digging trenches, except on the immediate front during an engagement, it was found desirable to do so by allotting daily tasks to the men, on the completion of which they might return to camp, rather than to keep them all digging a certain fixed number of hours. The first task consisted of digging the upper half of the trench, the second task completing it. With the normal profile as above described, the upper half of the trench exclusive of the first step and in a length of ten feet gave 6.1 cubic yards of excavation, and this was taken as a day's task. It was actually found that when men were worked by the day of ten hours that nothing more than this on the average would be accomplished, while on the task basis a good man would complete that amount

of trench, throwing the excavated material over the top, in four hours when working in ordinary clay or loamy soil. In fact, one of the engineer regiments reported that that amount of material had actually been disposed of by one man in two hours. In chalk, cemented gravel or stiff blue clay, the above task would constitute a full day's work.

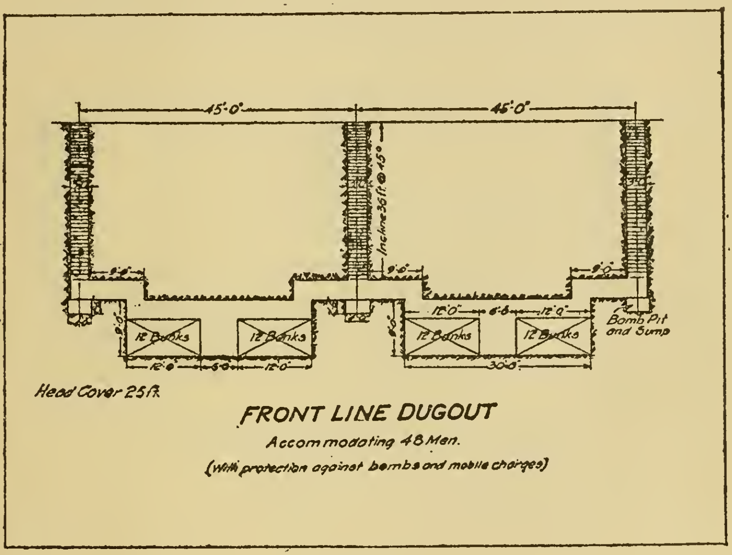


FIG. 10.

The lower half, or second task, contained four cubic yards of excavation and took about as long to accomplish as the first task, the lesser amount of earth handled being offset by the extra lift to the material. The average lift of the earth in the second task was about six feet, as it not only had to be lifted from the trench but thrown on top of the excavated material from the first task. Then, too, some rehandling of the excavated material was necessary in order to make room for new deposit.

Trenches were incomplete unless some provisions were made for giving the men living accommodations. These accommodations consisted preferably, and always if time permitted, in the construction of dugouts. While dugouts were being built, temporary and quickly made provision was furnished by shelters excavated in the banks and roofed over with timbers or concrete beams covered with as much earth as could be heaped upon them in the

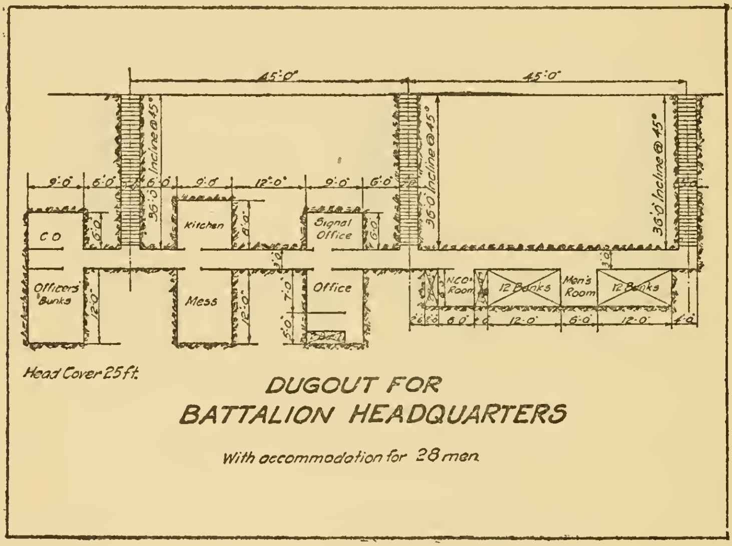


FIG. 11.

time available but without making them marked targets. Such shelters afforded protection against all shell splinters and even against a direct hit from a 77 mm. shell. In addition to these more or less simple accommodations there were needed in all occupied positions some place or places for headquarters, hospitals, storage of ammunition, etc., where reasonable protection could be had against direct hits from guns of almost any calibre, certainly up to those of 210 mm. (8.3 inches). Such protection could be secured only in deep dugouts under a

cover of undisturbed earth at least twenty feet in depth. There were many different designs for such dugouts, depending upon the character of the soil, the topography of the ground, the time available for their construction and the personal views of the engineer. But those shown in figures 10 and 11 were for their several purposes quite satisfactory and can be taken as fairly typical.

The dugouts were reached by inclines running down at an angle of about forty-five degrees with steps on the bottom. At least two inclines were given to every dugout, to prevent access being cut off and the men buried by a single lucky shot. They were driven like ordinary mining galleries and were lined with timber frames of three-inch plank, giving a clear opening three feet wide by five feet high. The galleries at the bottoms of these inclines had six feet head room and were also lined on all sides with planks, while the roofs and sides of the rooms leading off from the galleries were supported by ordinary miners' timbers. These dugouts were frequently lighted by electricity and were ventilated either by using the chimney from the cookstove, which if there were no other way of reaching the surface, passed up one of the inclines, or else by putting a brazier at the bottom of an incline, converting it into an upcast ventilating shaft.

Keeping dugouts free from water was not as serious a matter as at first thought it seemed to be. The clay subsoil in the war zone of France was usually impervious to surface water, so that the dugouts were as a general thing reasonably dry. The only serious matter in respect of drainage was to care for the water that might flow in from the open trenches. At the foot of the inclines small pits or sumps were dug to which hand pumps were attached and the water removed at intervals. The great danger in dugouts and in fact the only real danger, because most were quite safe against shell fire,

was gas, which flowing down the inclines, would remain in the dugout undisturbed for hours, perhaps even unnoticed.

As was explained in Chapter XVI when dealing with noxious gases, entrances to dugouts were covered by blankets soaked in gas-absorbing chemicals. In cases where gas attacks were to be expected frequently, these blankets were hung in pairs, separated by an interval of a few feet. They thus constituted a sort of air lock, preventing the passage of gas which would happen whenever a man would lift a single blanket on leaving or entering the dugout. With two blankets, one was always down.

In this discussion of trenches and dugouts it is assumed that time is available in which these elaborate structures can be produced according to plans, either when preparing a position in advance which, of course, means in anticipation of a possible retirement, or when a series of improvements can be slowly carried out while actually holding a front position.

In front of the forward trench were the wire entanglements intended to hold an attacking wave long enough to permit, even in case of surprise, a sufficient concentration of machine gun or rifle fire to destroy it before reaching the trench. To this end the entanglements were placed so close to the trench that it could not be approached or the wire cut without the knowledge of the sentries in the trench. And yet they were sufficiently far away to give the men a sense of security against immediate hand-to-hand fighting and so encourage deliberate careful aiming. A distance between trench and wire neither too short nor too long was from twenty-five to fifty yards. The rule was laid down that entanglements should never be placed in dead spots, to avoid which it was better to set them at a greater distance than normal. On the other hand it was very advantageous that parts

of an entanglement be subject to an enfilading fire from some portion of the Front trench.

There were many different ways of stringing wire, the result of individual views of different army engineers, but the general principle of construction was a fence with sloping wires in front and behind called a "double apron." The central standing portion resembled an ordinary barbed-wire fence, four strands high, attached to posts or pickets five to six feet long driven three yards apart and so deep that four feet were above the ground. Two yards in front, and also behind the main posts, were two rows of short pickets driven well down. Inclined wires led from the top of each fence picket to the anchor pickets, forming in plan a series of crosses. Three horizontal wires were attached to these inclined wires on each side of the central fence and spaced approximately equidistantly between the top and the ground, making ten horizontal wires in all.

In front, that is, on the enemy side of the forward apron, were usually two sets of low wire entanglements. Each of these consisted of two rows of short pickets projecting when driven about two feet above the ground and set alternately at three-yard intervals, with inclined wires running from the top of the rear picket to half way down the picket in front. If two sets of low wires were used, one row of intermediate pickets answered for the front row of one set and the rear row of the next, each row being two yards from its neighbor. About these inclined wires were twisted coils of loose unattached wires. There was a tendency of wiring parties to place too many wires, especially of loose coils, a tendency that was perhaps understandable though always discouraged when discovered. If there were too many wires, men could actually walk on them and trample them down to something like a heavy carpet. German wire entangle-

ments were much more complicated and consisted of several rows, as many as seven being not uncommon with horizontal wires, diagonal wires connecting the tops of the pickets, and some loose wires besides.

The entanglements were never continuous, gaps being left to give means of egress and return for the patrols who scoured No Man's Land nightly. These gaps were made by building the entanglements in sections of several hundred yards in length, according to local conditions, but having the end of one section overlap that of the next with an interval between. The enemy could not then see where the gaps were. In case an attack was feared, these gaps were closed by stretching across them "French" or "Concertina" wire, spiral coils of plain and barbed wire respectively. The first had a diameter of three feet six inches and, when pulled out, made a cylinder sixty feet long. The second was usually four feet in diameter and gave a length of eighteen feet. The concertina type was naturally more effective, but was more awkward to carry and to handle in an emergency. Both were held in place by pickets and were used not only to stop gaps, but to close roads and to create entanglements that in some emergency might have to be placed in a great hurry.

The pickets were of wood, when they could be driven by a maul without fear that the noise would attract fire. But when silence must be observed, as when new lines were being strung or old ones repaired in No Man's Land, screw pickets were used, made of round metal with one end twisted like a corkscrew so that it could be screwed into the ground, and with eyes to which the wire could be attached.

Wire entanglements could be cut and broken by shell fire. When an attack was contemplated they were subjected to a concentrated bombardment. When damaged by accidental fire, something of daily occurrence, the

engineers were called on to repair them at night, always a dangerous task, because probably notice of their presence would be given by the listening apparatus, when immediately the ground would be illuminated by some form of air bomb, which would burn for several seconds. Then the sharpshooters became disagreeably active. The best means of disposing of wire was the tank, which was able to smooth entanglements quite flat over which men could run subject to no more inconvenience or delay than possibly being tripped by loose wires.

The trench system, composed of at least three main lines and with any number of communications, switches, by-passes, etc., and with all the twists, turnings, and sinuosities, made a veritable labyrinth, in which men, especially new arrivals, might easily be lost. To simplify matters as much as possible, they were all named (and, of course, mapped) with the names in some orderly arrangement; that is, various stretches of the Front-line trench as, for instance, between adjacent Communicating trenches, were given names that began with the same letter, while similar sections of the Support and Reserve lines had other letters. Thus Georgetown, Gregory or Good would indicate locations in the Front trench, and Harold, Harwich or Henry similar locations in the Support directly in the rear. Communication trenches had their system of initial letters, as also switches or other irregular additions. Signs with these names were erected at every junction point like the signs at the intersection of streets in a city.

Through perhaps their long stay in France, the British went to great lengths in giving new names to places and localities. Some of the names being quite amusing. Treacle Trench, Tadpole Copse, Oxford Street and other designations certainly not of Gallic origin were placed on the maps, and undoubtedly many will rise centuries hence under distorted disguises to provide mate-

rial for heated philological discussion. Several such anglicized names will be found on the fragment of the map shown on page 227.

The enemy trenches were carefully mapped from air photographs and were likewise named, so that in the plans for an attack, various units would receive orders to capture and occupy the portion of the enemy trenches designated by name.

Under such conditions in dark, damp dugouts, in mud, in slimy ditches, to look from which meant instant death, exposed to constant wasting fire, and subject to bombardment or attack at any moment, the men of the allied armies had lived for three and a half years even before the American entry in the war, with all the relieving interest of open warfare absolutely unknown. The only change was when the period of line service was over and the unit was withdrawn for a few days' rest in the reserve, there to wait for it's next turn of duty in the trenches. Such life was more nerve racking than the sustaining excitement of a great offensive. Never have there been conditions of war that tried men's courage as those that existed from the first battle of the Marne until the final victorious movement began on the 18th of July, 1918, a period lacking less than two months to make four full years.

CHAPTER XXIV

FINAL PHASE

The drama was fast drawing to a close.

At the end of August, 1918, the headquarters of the First Army, A. E. F., had been temporarily located at Neufchâteau in the department of the Vosges. In September they were moved to Ligny and Bar-le-Duc in Meuse in order to be nearer the scene of activity, when the sector extending easterly from the Argonne forest to the Alsatian frontier opposite Nancy had been definitely assigned for American operations. By this date the American troops in France numbered nearly 2,000,000 men and the whole combatant force, except the Second Corps which was coöperating with the British and the recent arrivals still undergoing training, was concentrated on or immediately behind this front. All the units of the nine original engineer regiments that could be transferred from fixed duties were gradually moved during the month of August and September to the First Army area, with the exception of the Seventeenth and Eighteenth Regiments which could not be spared from the work of continued development of the wharf facilities at St. Nazaire and Bordeaux, and the Nineteenth, whose duties of maintaining locomotives and cars at Nevers and other points were paramount. The other regiments were not transferred simultaneously, nor even as complete units, but in separated bodies usually as companies and never larger than battalions, in order not to draw attention to the concentration that it was desired to effect quietly.

The sector described above included the famous St.

Mihiel salient which the Germans had held continuously since October, 1914, in spite of several determined efforts of the French to retake it. As the result of these failures both sides had settled down to the realization that the Germans were too strongly intrenched to be dislodged. A continued deadlock ensued whose quiet was broken only by an occasional raid or the daily exchange of a few shells. The tip of the salient lay on the high ground on the west bank of the Meuse. Included between the north and south limits were about four miles of the river Meuse, the Canal de l'Est, a canal of the first category, the two highways in the valley and the double tracks of the main line of the standard gauge railway connecting Verdun with the south.

The general plan laid down by the Generalissimo, Marshal Foch, was for the three forces, American, French and British, to make a simultaneous forward movement on the whole front from the Meuse to the North Sea, in which movement the American force was to occupy the right, thus leaving aside for the moment any offensive directed against the strongly fortified position of Metz. To make such a movement it was necessary first to reduce the St. Mihiel salient and recover possession of the railway and highway in the valley of the Meuse in order to have the physical facilities for transferring men and supplies to the Verdun portion of the front.

Accordingly on the night of September 12th the American Commander-in-Chief launched the first great American offensive. To attempt to storm the dominating hills of St. Mihiel would have been futile and suicidal, because during their four years of possession the Germans had strengthened the already strong natural position by every conceivable device of engineering science, and made it practically impregnable against direct attack. General Pershing, therefore, directed his main

offensive westerly from the Moselle at Pont-a-Mousson across the level plains to the hills lying east of St. Mihiel, of which Mont Sec was the dominating feature. In the early morning hours the attack was opened by an intense bombardment lasting until dawn, when the infantry "went over." At the same time some American divisions, aided by a French colonial corps, attacked on the face of the salient lying between St. Mihiel and a point east and south of Verdun. The offensive proved to be a great surprise to the enemy, although it was hard to understand why it should have been, because there had been a steady concentration of troops and of supplies for nearly a month previously and there was gossip all over France to the effect that a great offensive was planned for somewhere north of Toul. Perhaps the distribution of the knowledge deceived the enemy through its being so widespread and led him to believe that the reports were being purposely circulated with intent to deceive. At any rate the first day's objectives were quickly occupied with surprisingly small losses and the flow of prisoners who began to appear early in the afternoon were evidence that the enemy was beaten. The quality of the prisoners gave much hope that the end was not far away, because among them were many old men and boys, who in conversation did not hesitate to admit that they were surprised and by the fierceness of the assault completely routed.

During the night of September 12th-13th the Germans evacuated St. Mihiel itself without firing a shot in its defense, and all their labor spent in digging miles of trenches, in raising acres of wire entanglements had gone for naught. They saw clearly that, if the American attack were resumed on the morrow and pressed with the same vigor that it had been during the 12th, the whole garrison would be cut off and be compelled to surrender. If they were to leave at all and of their own volition it

must be then and under the cover of darkness. The next few days saw not only the long maintained salient abandoned but a wide belt of country in the rear recaptured. The Germans, as a matter of fact, fell back considerably more than they were expected to do. They apparently fancied the attack to be the beginning of one in force on Metz and hastily withdrew to cover that important gateway to the Rhine valley. They learned when too late that it was only a move to clear the way for the greater offensive from the Meuse westward. Afterward the Second Army, A. E. F., made complete preparations for a drive on Metz and to the eastward of Toul, but the signing of the Armistice on the very eve of the attack stopped it before it began.

In the St. Mihiel offensive the work that the engineer regiments accomplished was chiefly in the matter of lines of transportation. They took over the French system of light railways which served their old front, and followed up the advance with new lines connecting them with the well built German system which the enemy had not been able to destroy, so quickly did he retreat. All this involved new rail-heads, new storage depots, and new means for local distribution. Roads had to be repaired, actually rebuilt where they crossed the long abandoned territory lying between the lines where they had been pounded by the shells from both armies during more than three years; mine craters purposely blown up at road intersections had to be filled in with logs, earth or the débris of houses; new water supply points established and a great mass of other details attended to in order that the combatant forces could advance and, after they had advanced, be supplied. Then there were the standard gauge lines to be operated, lines that had been long unused, that freight in broad-gauge cars might be run as far forward as possible without breaking bulk or being transferred to the smaller light railway cars.

A meter gauge railway, belonging to the local communal system running northeasterly from Commercy, crossing the German trenches at Apremont and then skirting the base of Mont Sec, occupied a very desirable location for a standard gauge line, and it was decided to widen the gauge.

This little railway had been completed in the summer of 1914 and consequently had never been operated except for a few weeks. Four years later it was completely overgrown with grass. Having decided to reconstruct it the 11th Engineers were instructed to make the plans and preparations but were forbidden to begin work in the field until the offensive had actually commenced for fear of drawing the attention of enemy airplanes to new work in progress. The track consisted of fifty-pound rails laid on ties two meters (6½ ft.) long but held by screw spikes. Prior to the engagement a few men, widely scattered, were set to work drawing the spikes, while timbers were collected with which to strengthen the bridges. On the morning of the 12th the engineers began to move the rails outward to the broad gauge, using for the moment the small ties, thus giving at once a track over which could be and was run a construction train carrying standard gauge ties, with which the track was relaid. The light rails were permanently retained and did good service.

Beyond the German trenches the roadbed was found to be in bad condition. They had removed all the track material for use in light railways, since a very short and independent line with a gauge of one meter and connected with no similar railway in their area had absolutely no value for them. Large craters existed where the Germans had blown up the roadbed, but apparently long previously to their retirement, so that north of Apremont the whole line had to be largely rebuilt. When this was done it constituted the chief standard gauge

connection, and with a rail-head and transfer station at Woinville it functioned in connection with the reconstructed and extended light railway system.

During this and the immediately subsequent Argonne-Meuse offensive the work of the engineers was noted not for remarkable or spectacular individual pieces of construction, but rather for the large amount of work done as a whole and its widely varied character executed under the most trying conditions. Time in such circumstances is the governing factor. Railways, roads, water supply and trenches that are to be constructed must be conceived on a plan that will lead to the quickest results rather than give a perfected structure to which the author may subsequently point with pride as an example of his scientific skill. The polish and neatness with which a conscientious engineer likes to finish construction entrusted to his care must be quite lacking in work done during the stress of battle. Under such circumstances the highest type of engineering is that which produces a given result in the fewest hours, regardless of permanence or economical operation. It is for this reason that the work accomplished by the engineers in these two offensives, great in scope and varied in type as it was, presents but few examples of accomplishment worthy of extended engineering analysis. As one measure of the mass of work accomplished, the number of standard gauge trains moved by a single regiment (the Thirteenth Engineers) is interesting. This regiment, occupied wholly in the operation of railways on that part of the French front, including St. Mihiel, Verdun and the Argonne, moved no fewer than 17,315 trains, the greater part during the American offensives, carrying nearly 9,000,000 tons of freight with an unknown number of passengers which certainly ran into millions, when all movements and counter movements of troops were counted. During September and October, 1918, when the

Argonne offensive was in progress, this same regiment handled 3,082 trains with 2,400,000 tons of freight.

In the execution of work during a great offensive there were frequent disappointments and much discouragement. Often after finishing the construction of a bridge, or railway yard or important water point, done under the most trying of circumstances, including rain, wind, cold, little food and sleep, a sudden change in battle plan would render it all unnecessary, or an enemy raid would capture it, or, what was of frequent occurrence, the enemy, advised of the construction, would wait until the last member had been put in place and then, with their long-range guns, knock it all down like a house of cards. A fine example of this last experience was a French railway viaduct in the Vosges, crossing the valley of the Largue. This handsome structure, like so many other similar ones in France, sources of joy to the artistic, and of interest to the scientific man, was about 460 meters long with an average height of twenty-one meters and consisted of a series of forty-two arches of a span of 8.6 meters each with a central arch over the river with an opening of twenty-five meters, all constructed in brickwork. While the retreat of 1914 was in progress, the French, fearing that this important structure might fall into the hands of the Germans, destroyed its immediate usefulness by blowing up the central arch and the two adjacent arches on each side. In the following spring, when fear of a further German advance on this front had disappeared, the French, who needed the railway for their own service, decided to rebuild the viaduct. With the customary French desire for good workmanship and not yet having learned the lesson that such standards have no place in war, the engineers reconstructed the broken part in reinforced concrete and restored the original artistic outline of the stucture. On the night of May 25, 1915, the rebuilding

had been finished without any untoward incident and they began to remove the falsework and arch centering. Four days later the enemy opened fire with a gun of 420 mm. ($16\frac{1}{2}$ ins.) calibre at a range of about 12 km. ($7\frac{1}{4}$ miles). In a few hours fifty-one shots had struck the bridge or fallen in the immediate vicinity. The structure was in ruins. A length of 120 meters was completely demolished, and the central arch with four small

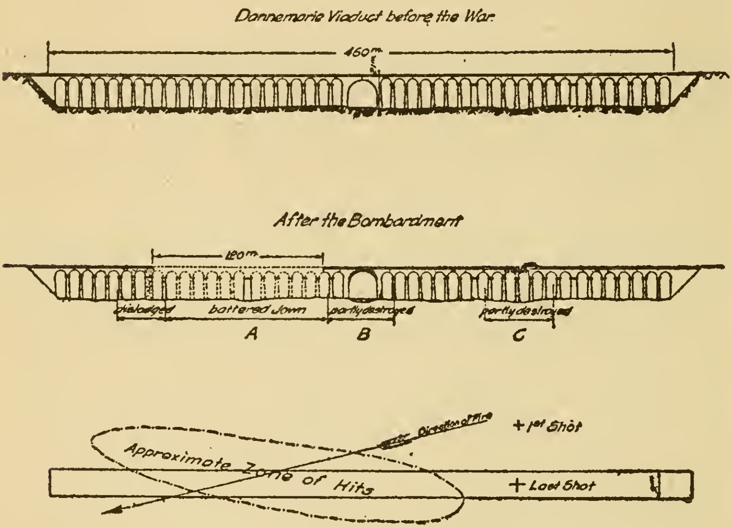
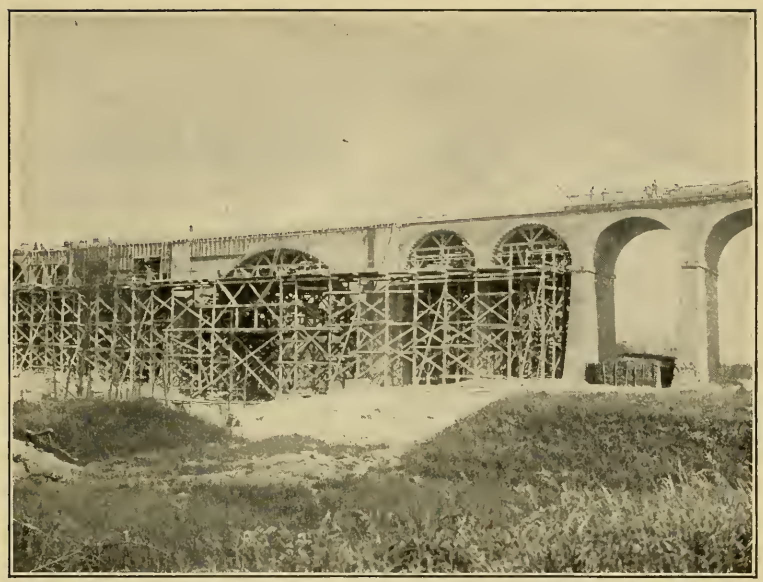


Fig. 12.

arches were severely damaged. The Germans had waited until the reconstruction was completed and then bombarded it, the fire being directed by aviators.

The pictures opposite, copies of official French photographs, illustrate the construction and damage. It will interest engineers to know that the reinforced concrete, although fresh, resisted destructive action better than the brickwork, and the attention of engineers is particularly invited to the fact that great masses of the brickwork in one of the piers were moved laterally without



MAY 25, 1915. FRENCH RECONSTRUCTION FINISHED

MAY 30, 1915. EFFECT OF GERMAN ARTILLERY FIRE

DANNEMORIE VIADUCT

Its Replacement by the French and Immediate Destruction by German Artillery from a Distance of More Than Twelve Kilometers

internal disturbance and solely by the effect of concussion of an exploding shell transmitted through the air.

The diagram of the Dannemorie viaduct over the Largue shows the pre-war elevation, the parts demolished by the bombardment and the extraordinary accuracy of the artillery fire, every shot either actually hitting the bridge or falling within a maximum error of less than fifty feet in the case of the first shot. After this costly experience the French effected a crossing of the valley on a low and easily rebuilt wooden trestle, one that was not worth the expenditure of ammunition to destroy.

With the St. Mihiel salient removed and the arteries of travel in the valley of the Meuse restored to French control, the way was open for the main general offensive. If there had been idle talk about the St. Mihiel attack, there was none about the other. Commanding officers were aware that some movement was at hand, but beyond orders to hold their commands in readiness for any emergency they knew nothing definitely. Therefore, the experience of myself and my regiment was typical of that of many others. On September 22d I was warned that we would be moved presently, and on the morning of the 24th I was ordered to proceed immediately to Vraincourt, a small village just east of the Argonne forest, and was advised that trucks would carry a part of my regiment during the night.

For some days there had been much activity after dark. From dusk each evening until early morning there was a steady procession of guns, trucks loaded with ammunition and men, and wagon trains of every description, all moving north, sure signs of something big at hand. During the night the procession never paused. It camped by day, leaving the roads empty and thus concealing the movement from aerial observation.

Before daybreak on September 25th the Eleventh

Engineers arrived at Vraincourt and, in accordance with orders, remained under cover. Vraincourt had been selected as a place of concealment as well as being convenient for headquarters, because it had never been shelled systematically and was believed to be unknown to the Germans, as certain captured maps did not show its location. This proved to be an idle empty dream, for Vraincourt was heavily shelled that very day. Some of the Fourteenth Engineers were quartered in the village and two companies of the Fifteenth Engineers nearby.

All knew that the battle hour was not far away, perhaps to begin that night, but of this no one was certain. At 11 P. M. there were some sharp artillery exchanges, which died down after twenty minutes. At 2 A. M. on the 26th there was heard a sudden violent roar. After ten minutes with no sign of abatement, it was evident that the zero hour was passed and that, what might be, and in reality was, the greatest battle in history had already opened. It did not take me long to dress and to reach the hilltop behind which Vraincourt had received, during nearly four years, some small measure of protection. It was a wonderfully glorious night. Every star was shining brightly in the crisp cool air of that September morning, while the moon, strong in its third quarter, revealed all the features of the scene. Below, running east and west was the valley of La Couzance, a tributary of the river Aire which, after picking up its little affluent at a short distance to the left, continued its course to the north into the territory that had been continuously in German hands since September, 1914. Down in the valley lay a dense white fog, and buried in that fog were some large French naval guns on railway cars, that had been run into place during the immediately preceding nights and covered with camouflage.

On the slope of the ridge in front there was a series of constant flashes, looking for all the world like giant

fire-flies. They were not fire-flies but flashes from guns close together, row on row, being loaded and fired with all the rapidity that modern gun mechanism made possible. Although directly in front the flashes of the individual guns could be seen, one began to lose them to the right and left, or rather they began to blend into greater lights, at first like brilliant sheets of so-called summer lightning, only at very short intervals. Then in the farther distances these sheets themselves blended and the sky became lurid as by a great conflagration with similar throbbings of intensity. In the valley below the naval guns were being fired more slowly, and as each one was discharged, though the flash could not be seen, an area of the fog bank turned for an instant red and yellow. Thousands of guns over miles of front were in action.

The noise was as grand and as awe-inspiring as the sight, and can perhaps be best compared with that of a wild ocean storm pounding on a gravel beach. There was a continuous roar, the mingled sound of the distant guns, like the steady roar of distant surf. On this background of sound there stood out the separate discharges of the nearby guns, with the deep-voiced punctuations of the big naval pieces dominating all, just as the crash of individual waves can be distinguished above the confused din of the storm. It was a sight to hold one for an hour spellbound; when suddenly, as if nature herself had been aroused to jealousy and to a spirit of competition, a great white meteor drifted slowly and silently across the sky.

I went down to the valley through the ruined village of Courcelles, whose broken, jagged walls looked like gaunt spectres in the moonlight. A sanitary train had taken refuge under the lea of a kind bank. It had been ordered to take post in the village but the commanding officer, fearing that the enemy guns, in retaliation for the punishment they were receiving, might select the village

for one of their targets, had stationed his train just outside. The enemy, however, was too busy trying to escape the fearful deluge of shells to have time for reply. In the valley some stragglers inquired how to find their divisions, an ambulance stopped to ask for the sanitary train, while trucks heavy with shells to feed the ever-hungry guns went lumbering by. Orders to lengthen the range were coming by telephone to the naval guns from some advanced observation point, for the moment had come for the infantry to go over the top.

It was all a great prelude before the curtain rose for the final act. Then the sky began to turn gray, and the stars to fade, warnings that day was breaking and that a return to camp must be made for a hurried breakfast so as to be ready to execute the orders already received as against this very hour.

The work of the army engineer troops in the Argonne-Meuse offensive was in principle similar to that in the St. Mihiel offensive, but on a larger scale, over a more extended area and for a longer time. As always the great demand was for transportation facilities. In the sector over which the American part of the offensive was conducted there was a great lack of railway lines. The character of the topography had not encouraged construction before the war beyond meeting the bare local necessities and these accommodations even if in the best of condition were absolutely insufficient for the present exigency. There was the main line running east toward Verdun, parallel with and just behind the French battle front as it had remained stabilized. This was the line that the Germans had cut by shell fire and rendered unusable in their Verdun attack in 1916. It had not since then been put into operation. The American engineers reopened it, however, immediately following the commencement of the American offensive. There was another double-track railway following the Meuse north from

Verdun to Sedan. The latter railway existed only in name. Crossing as it did the field of the intense fighting in 1916 where the tide of victory had flowed and ebbed so many times, especially over the hill known as Le Mort Homme, the railway was found to be in a condition that required complete reconstruction as soon as the enemy was forced back sufficiently to permit details from the Eleventh and Fifteenth Engineers to undertake it. The roadbed was full of shell holes, bridges were down and the only rails left in place were broken and twisted, because both sides in turn had removed rails fit to relay. These two railways were the only standard gauge lines serving the field of the Argonne-Meuse offensive over which the American operations were to be conducted. The latter of these was quite out of service, while the former had but one main track connected for running and was without yard or siding facilities. There was no other existing railway in front of the Americans until the main east and west line through Sedan was reached, and that line was not captured from the enemy until the very last days of hostilities.

The Germans had made up for their own deficiency by constructing a fairly complete light railway system with the 60 cm. gauge, which gave them all the facilities they needed for the transport of supplies along what had been an inactive front since the French counter-offensive in front of Verdun had come to an end in 1916. As was usually the case, the German light railways were found to be in excellent condition with heavy rails, that is, heavy for light railways, and heavier than those ordinarily used by the allies for similar tracks, with good ties and a sufficiency of ballast.

The Chief Engineer of the First Army decided to meet the railway shortage, so far as the American needs were concerned, by reconstituting the Verdun-Aubreville line with its access to St. Dizier, an important supply base,

to construct in connection with it additional side-track capacity, to rebuild the Verdun-Sedan line as fast as it was recovered from the enemy and, at the same time, to build a new standard gauge line along the eastern edge of the forest of the Argonne from Aubreville, following the valley of the Aire through Varennes to Apremont (not to be confused with the Apremont, east of St. Mihiel), where it was expected to make connection with a previously existing single-track line that had a terminus there. When, however, Apremont was reached it was found that the Germans had rebuilt the standard gauge railway into one with a gauge of 60 cm. The railway was pushed through to Varennes, the place where Louis XVI was recognized and captured on his flight from Paris. At Varennes an extensive rail-head was established until the advance had progressed sufficiently beyond to permit the extension to Apremont, with subsequent reconstruction to Grand Pré. This railway became the main line of American supply on the west.

The light railway system was extended as the front went forward, captured German lines and even German rolling stock being used. Much of the latter the enemy had succeeded in withdrawing at least to the limits of the light railway system, but the tracks as a general thing were left intact. All high roads were in bad shape and quite insufficient to accommodate the enormous traffic incident to the huge army of 1,200,000 men.

As in the case of railways, the best location for highways had been in the valley of the Aire. Elsewhere routes would have had frequent and abrupt changes of gradients, since those with a northerly direction ran across and not with the deeply marked lines of natural drainage. But the old national highway through Varennes was impassable. The principal bridges had been blown up or damaged by shell fire, while the French had deliberately fired a mine in an embankment about

AMERICAN ENGINEERS REPLACING A BRIDGE AT GRAND PRÉ, THREE TIMES DESTROYED BY SHELLS

forty feet high just behind their front line, south of Boureuilles, completely annihilating it and digging a great crater in addition. This they did to block the road against a possible German advance. Curiously enough the Germans did precisely the same thing behind their lines but, of course, like the French, they did this many months before any offensive was even contemplated. The double act indicated how both sides on this front had conceded a state of deadlock to exist and, having abandoned all expectation of advance, took steps to hinder a possible advance by the enemy should he attempt it.

Until a standard gauge railway could be built, a task necessarily involving considerable time, a time that was not shortened nor the task made lighter by the heavy rains, the Varennes highway was the only artery over which troops could move, the long trains of guns, ammunition, food and supplies of all sorts go up and the endless procession of ambulances come back. Temporary detours around the craters were constructed until a detachment of French bridge engineers with their well equipped field mobile plant could bridge first the greater gap and afterward the smaller one. As the major one of these detours or run-arounds had steep gradients which were not metalled, the heavy trucks with their loads of ammunition soon dug deep ruts, in the soft mud of the temporary road, that called for a superhuman effort to get traffic through at all. There were times when the road was blocked with two lines of vehicles for miles, and everyone was in constant dread that the Germans would shell it. They could easily have done so, but for some unknown reason did not. Finally some of the Twenty-third Regiment and other engineers of the road service department succeeded in getting the obstacles removed and the traffic moving as freely as battle conditions permitted.

Such offensives as that of St. Mihiel and, to a greater

degree, that of the Argonne-Meuse on account of its longer maintained advance, made strenuous demands on the Water Supply Troops who had to keep up with the advance. The Germans had a well established system of their own which, fortunately, they could not, or at least did not, destroy as they fell back. While the supply was sufficient for their own consumption, it was not so for a force many fold greater. In the St. Mihiel offensive the Water Supply Regiment prepared in advance seven pumping plants, twelve reservoirs or tanks, installations for filling carts and collected 25,000 feet of piping for the laying of new lines. As the attacking troops went forward the Water Supply Engineers followed close on their heels, rendering available the local sources of supply, setting up the canvas reservoirs to receive water hauled forward by motor tanks until permanent water points were established, converting three captured German installations to American use and locating animal water points with the necessary troughs. To assure purity of supply while examinations were made, two sterilizing installations with connected storage tanks were operated in addition to five mobile purification plants on motor trucks. During the first six days of the offensive, over and above the water obtained from wells and local sources, 250,000 gallons of water were delivered by motor trucks besides a large but unrecorded amount hauled in light railway tank cars, holding 2,000 gallons each.

For the Argonne-Meuse offensive the previous preparations were similar, including the assembling of complete outfits of pumps, reservoirs and sterilizing plants. Immediately after the attack was begun, steps were taken quite like those of St. Mihiel. At first hand pumps were installed by means of which the portable canvas reservoirs were filled, whence water was carried forward and distributed by the ever-useful motor truck. Finally, the permanent erections were accomplished to

the number of no less than seven gravity and thirty-one pumping stations, exclusive of many water stations for standard gauge and light railways and all in addition to the existing sources of supply found and captured.

On November 10th the First Army, A. E. F., had reached Sedan, had swept the enemy from the valley of the Meuse and back to the northern frontier of France. The Second Army was on the point of attacking through Alsace when at 5 A. M., November 11th, the Armistice was signed and orders were flashed along the whole line to cease firing at 11 o'clock. Hostilities had at last come to an end. The problem that faced the engineers nineteen months earlier had been solved. An army of 2,000,000 men had been transported overseas, the railways and roads, ports and wharves, storage yards and depots had been constructed, and the correlated services for water supply, motor transport, camouflage, mapping, chemical warfare and the more delicate operation of range finding had been organized, while trenches had been excavated and dugouts driven. It was a great work. Mistakes, of course, had been committed, but they had been made unavoidably and pardonably. There remained an accomplishment of which the members of the profession of engineering and the people of the country may well be proud. From a small handful of trained military engineers there had grown a tremendous army of engineers with experience in every field of applied science. The details of the problems that were presented to them were new, the task as a whole was stupendous, but in setting out to solve the former and to accomplish the latter, they took for their guiding spirit the motto of the Corps of Engineers which had been handed down from that eminent French engineer officer, the founder of the corps, Major L'Enfant, a motto denoting a modest confidence that is based on hope with a determination that knows no fear —

"ESSAYONS"

CHAPTER XXV

ORGANIZATION OF ENGINEER TROOPS IN THE FIELD

The organization of engineer troops, their control and the assignment to them of duties varied considerably in the three principal allied armies. The best illustration of this difference in practice is perhaps in the case of troops engaged in the work of transportation, the largest and the most important field of engineer activity. The principles, underlying the composition, organization and equipment of railway troops, in force in the armies of the United States, France and Great Britain are typical of the principles adopted for other special engineer troops. As military engineering is now a matter of broad civil engineering, the question naturally follows whether some of the principles on which the special troops have been organized do not find application to all engineer units in the army of the United States. Heretofore the army has not recognized the close connection between many of the engineering features of civil and military practice to the same extent as did the armies of some foreign countries.

At the outbreak of the war in August, 1914, the British organization of railway troops consisted of only two companies of Royal Engineers, out of whom and on whom had been built the large and complex transportation structure that existed when the war was ended, an organization that finally included more than 100,000 men. One of the first steps taken by the British General Staff toward the creation of a special railway corps was to accept an offer made by the Canadian Pacific Railway Company to furnish a detachment called the Canadian

Railway Overseas Construction Corps, which consisted of two companies under the command of a major, every man in it being carefully selected. So satisfactory was the work of this corps that further calls were made on Canada to send more such men to meet the ever increasing railway needs. The British set a high value on these Canadian railway troops because they believed that the standards of the rapid and temporary character of railway construction as used in western Canada more closely approximated war conditions than the thorough, elaborate and permanent standards of Great Britain. This experience of the Canadians proved to be particularly valuable. The Canadian troops were organized in conformity with British infantry regulations on the basis of battalions, each battalion consisting of thirty-four officers, sixty-one warrant and non-commissioned officers, and 1,010 men, a total of 1,105 of all ranks. These battalions were sent overseas with an equipment extensive in character and elaborate in detail, and were completely self-sustained units capable of undertaking railway construction of any kind and on any scale. Their equipment, in addition to a very generous supply of small tools, included wheel and drag scrapers, road-grading machines and grading plows, large and small motor trucks, horse-drawn wagons, surveying and telephone outfits and in some cases track laying trains and steam pile drivers.

The Royal Engineer unit in the British army was a company consisting of six officers and 250 non-commissioned officers and men. Originally the companies were under the command of two captains, one of whom had charge of all matters of administration and the other of work. It was finally found desirable to assign to the first-named duty an officer with the rank of major, so as to insure one of more years with corresponding experience and judgment. These companies when engaged on railway work were furnished with a supply of all the necessary small tools

but had no surveying outfit, nor were they equipped to undertake heavy construction. So far as possible they were permanently quartered in railway cars which were moved from place to place as needed, thus giving to each unit the maximum of mobility. The personnel of these companies was carefully selected and consisted of representatives of the various skilled trades likely to be used in any form of railway construction, such as trackmen, bridgemen, masons, machinists, etc. For what is known as common labor they depended on having unemployed infantry units, or special service or labor battalions attached to them. Equipped, as above stated, with all the necessary small tools, they drew on some central depot for large machine tools such as pile drivers, steam shovels, derricks, or grading machines if needed. Although they worked side by side with the more fully equipped Canadian battalions, it was the custom to leave to the latter all work of a heavy character, the British Royal Engineer companies doing the lighter work that was more easily handled by a mobile unit. The whole theory in the British army was that the Royal Engineer companies were not organized to plan or lay out work but were intended for execution only.

The planning and the laying out of work was done under the direction of a regional engineer called a Railway Construction Engineer, or R. C. E. as he was always known. He had under him Assistant R. C. E.'s in charge of districts, each assistant with the necessary survey units, and the engineer companies reported to them for work orders only. The Construction Engineer had nothing to do with any question of the internal administration of the companies. The R. C. E., whose region of control was approximately that of an army, in turn reported to the Chief Railway Construction Engineer (C. R. C. E.), a departmental officer on the staff of the Director General of Transportation.

During the first two years of the war it is rather curious to note, as an instance of the existence of the composite character of the British army, that the Canadian troops and the Royal Engineers reported to quite separate authorities. The former had their own Brigadier-General commanding, while the Royal Engineers were all under the Chief Railway Construction Engineer. Before the war closed this anomalous system was simplified by creating a Director of Construction, through whom all these troops received their orders, including those engaged in the construction of light railways. The Chief Railway Construction Engineer, and subsequently the Director of Construction, had jurisdiction over all matters of construction whether within or without the zone of the armies, in accordance with the basic principle of the organization of the department of transportation. This centralized control of railway construction the British found worked well and was preferable to allowing each army to do its own work separately. They believed that the unification thus obtained obviated any possibly injurious competitive struggle between two zealous army commanders for the necessarily limited supply of men and matériel.

Besides the railway construction personnel the Chief of Railway Construction Engineer also had control of the large and small tools and supplies such as rails. Under him were pooled the men and equipment thus rendered available for use at any point. He had his main depots for tools and matériel upon which he could draw to meet any emergency or to make good deficiencies. In addition to the base depots there were the smaller dumps under the jurisdiction of the several Railway Construction Engineers.

In the French army there was an organization of railway troops that had been in existence for some years before the war. The French General Staff realized, to

some extent more than the British did, the important part that transportation would play in a future war, although their estimate failed to fully measure the situation as it actually developed. The French had, as has been explained before, one advantage over the two associated armies in that they were operating in their own country and in connection with their established railway systems which carried the burden of their separate administration. Practically speaking, from a military construction point of view, there were for the French no lines of communication.

As part of the regular establishment during times of peace there had existed a regiment of railway troops known as the Fifth Regiment of Engineers, or as they were called in French, "Sapeurs de Chemins de Fer." This regiment under the command of a colonel was really a training corps. The course of instruction extended over a year. In addition to their military duties, the officers and men were instructed in surveying and all the details of military railway construction and operation, including track, bridges, buildings, rolling stock, water supply, and telegraph and telephone lines.

The instruction was thorough and practical, the Government availing itself of its ownership of the state railway attached both the officers and men to the staff of that railway during a part of the school year. Connected with and working alongside of the Fifth Engineers was the Ecole de Chemins de Fer, with a central office at Versailles and a large park for the storage of matériel located near there. This school was a permanent establishment and continued to function during the war, as it was charged with the collection and keeping of all railway matériel, the administration of repair shops, the organization of technical bureaus, methods of instruction, and all matters of personnel.

The peace footing of the Fifth Engineers consisted of

nineteen construction companies, one supply company and one company of drivers for both horse-drawn wagons and motors. Each company was composed of six officers, two captains and four lieutenants, with 200 men. Of these nineteen companies, sixteen were stationed with headquarters at Versailles for purposes of instruction, and three were territorial companies located in the French colony of Morocco. The total peace footing of railway troops was, therefore, including the headquarters staff, 126 officers and 4,200 men. This was a considerably more numerous and highly trained organization than the similar corps with the British army and one that provided an excellent foundation on which to build a complete war organization, especially as the men had been so thoroughly trained.

The administrative functions of the commanding officer of the Fifth Engineers changed immediately on the commencement of the war. As an officer of instruction his duties obviously ceased. The companies of his regiment were at once scattered and attached to other officers for work, over which work he exercised no control. His duties were limited practically to matters of discipline in the so-called regiment and to certain questions of personnel. Although the regimental organization remained in nominal existence, it had ceased to function. To all practical purposes the French adopted the separate company system exactly the same as the British, as each company was a distinct entity so far as its internal administration was concerned. The regimental form of organization of the regiment was a highly convenient arrangement for administrative purposes during peace, but the French contemplated dropping it and actually did so during the period of hostilities, when something more elastic was needed, reverting to it when the emergency had passed.

Attached to the Ministry of Public Works was a gen-

eral officer with the title of Directeur Général de Transport Militaire, which for convenience was abbreviated to its initial letters — D. G. T. M. On the staff of each army commander there was an officer, usually of the rank of Colonel, to whom was given the title of Directeur de Transport Militaire de l'Armée (D. T. M. A.). This officer ascertained the army needs, prepared the general plans, and submitted them to his superior, the Directeur Général for approval and execution. The latter was charged, therefore, both in theory and practice, with great powers and responsibility. He not only had under his orders all the railway troops but, during the period of the war, the plant of the school at Versailles, and he exercised authority through the Minister of Public Works over all the commercial railway systems of France.

One thing which stood out in the equipping of these special troops was the work trains composed both of motor trucks and railway cars. These work trains possessed the quality of mobility in the greatest measure. So excellent were they that the British copied them. The motor truck trains consisted of three vehicles. The first vehicle was a motor truck and tractor combined, containing the machine and hand tools for both metal and wood workers, engaged in the various trades of fitters, blacksmiths, miners, boiler makers and carpenters, and with tools for the cutting of rails either hot or cold. The second vehicle was designed for the conveyance of workmen with the necessary hand tools for track grading stored beneath the seats. The third vehicle was equipped with an electric generating three-kilowatt set of 200 volts, with electric drills for both wood and metal workers and a lighting plant. These motor trucks were exceedingly mobile and could be run from point to point with great convenience. They contained everything both in the way of tools and men that might be necessary for

the repairs of lines abandoned by the enemy, or work of a temporary character preceding the more permanent reëstablishment of the track.

The work trains of standard gauge railway cars were of two kinds, the "Parcs sur Rails" according to the French official designation and the train work shop or "Train Atelier." One Parc train was supposed to be attached to every company of railway troops and formed their park of heavy tools and materials. It consisted of seven cars which contained:

a. Tools for various mechanical trades, carpenters, tinsmiths and plumbers, lumbermen, telegraph and telephone lineman, tracklayers, masons, miners, blacksmiths and fitters.
b. Lighting plant.
c. Transport vehicles, wagons, motor trucks and railway inspection cars.
d. Explosives.
e. Ejector pump.
f. Steam pile driver.
g. Derrick.
h. Lifting tools, blocks, tacklés, jacks, etc.
i. Switch apparatus.
j. Trestle timbers and irons.
k. Small boat.
i. Library and drawing equipment.

With such a train, capable of being easily moved, a company of skilled mechanics assisted by service battalions could execute almost any work.

The work shop trains were more elaborate installations, intended to make up for the lack of industrial machine shops existing in the devastated regions at the front, one train being assigned to a group of companies. A force as large as several companies combined and with the aid of a Train Atelier, could execute very heavy reconstruction, including that of large bridge trusses.

These trains were composed of nine cars, one containing electric generating sets to produce power for operating the tools, two others were equipped with large machine tools, one contained a forge and foundry, and another wood-working tools, one held material, one served for an office, while two were devoted to tools and supplies for pneumatic rivetting. The only equipment that could compare in completeness and efficiency with these Parcs and Ateliers were similar German trains.

The French, and the British to some extent, did not limit mobility to the working force, but extended the benefits of it to the regional officers. Each Director of Army Transportation (D. T. M. A.) of the French service was housed permanently in exceedingly well appointed trains, in which were not only lodging and boarding accommodations for himself and staff, but designing and clerical offices. These trains were moved from place to place, so that the Transportation Officer could be in close contact with the operations that were most important at the moment. On the train was a telephone exchange and a generous supply of wire and field equipment, so that after a train took a new station the D. T. M. A. was put in direct touch with headquarters and other points.

The motor trucks were supplemental to the railway trains. In the case of an advance the motor trucks could go beyond the rail-heads and make the first repairs or track restoration, permitting the heavier railway trains to follow and establish a permanent way. In addition to these trains, the French had on hand in the school at Versailles a very complete collection of machine tools of all kinds, consisting of grading and track-laying trains, excavators, electrical screw-spiking machines to drive the French screw spikes, drilling sets to drill spiking holes in wood ties, light manual cranes for the handling of rails, portable field electrical light plants for work at

night where not exposed to direct enemy fire, mobile and semi-mobile steam engines, pile drivers, compressed air outfits, cable conveyors, concrete mixers, all the plants necessary for water supply and drainage, including well-boring outfits, a very complete supply of various types of bridges from rolled beams to girders for various lengths of spans to as great as forty-eight meters, ties, timbers of various dimensions, and rails with their fastenings.

The railway section of the French army was an organization well conceived, thoroughly trained and completely equipped. It had a complement of officers who were masters of railway construction and operation, under whose leadership great results were achieved with the maximum of expedition and the minimum of friction. The French system of organization and equipment is one deserving close study by our own authorities, if the lessons of the war are to be taken to heart.

The American system of special troops differed radically from either the British or the French system. When the United States entered the war, there were two regiments of engineers actually organized, with five others authorized and in a more or less advanced state of development. These troops were intended for general military engineer work so that there was nothing in existence comparable with the French Fifth Engineers, or capable of executing undertakings calling for specialized technical skill. The first step towards raising such units was in the call for volunteers for the original nine engineer regiments, intended primarily for railway construction, maintenance and operation. These regiments were followed in quick succession by others for water supply, forestry, roads, mapping, and the other fields of engineering, as well as for assignment with divisions as sappers. The manner in which these regiments differed from corresponding units in either of the other

armies was in size. In their first constitution the Tables of Organization for Engineer Troops were followed, which called for thirty-three officers and 1,038 men, or a grand total of 1,071. Subsequently the Tables of Organization were changed and an engineer regiment on a war establishment was fixed at a total of 1,700 officers and men, consisting of fifty-four commissioned officers and 1,646 of other ranks. In actual practice it was an exceedingly rare occurrence when any one engineer regiment, except the engineers attached to a division, worked together as a unit. The experience of other engineer regiments, certainly of every one working in the advanced area, was that the component parts were separated, sometimes very widely. Not infrequently they were detached from the command of their own regimental commanding officer and assigned to the temporary command of others.

The analysis of the make-up of an engineer regiment shows that out of the fifty-four officers eighteen of them were attached to regimental and battalion headquarters, and out of the 1,646 men 116 served under similar assignment. That is to say, while thirty-six officers were serving with their companies, no less than eighteen, or half as many, were with headquarters. Of the men 7.6 per cent were in the category of what would be termed in civil life, overhead expense.

Such a heavy proportion of officers and men in nonproductive capacity involved in the first place a waste of man power and in the second, inefficiency. An American engineer regiment was supposed to be a complete entity. So it should be and was when used as a division unit. Consequently, in accordance with the official establishment, it had among other sections a topographical officer with all the necessary surveying instruments and men to handle them. Commanding officers of regiments were, therefore, expected or required to do the surveying for, and detailed planning of, work entrusted to them for

execution. But it usually happened that the headquarters of a regiment moving with a part of a regiment assigned to some particular piece of construction, would generally arrive on the very eve of the undertaking. The commanding officer would in such case have to make his own studies, without previous investigation or information, instead of devoting his time and the energy of his men to the carrying out of plans already digested. The result was frequently lack of proper preliminary examination and consequently inefficiency in execution.

With the French and British systems all this was entirely obviated. There was no waste through high ranking officers in regimental headquarters being partially unemployed, because each company, the work unit, had only the minimum number of officers necessary, while officers of more advanced standing served on regional or army detail. There was no lack in efficiency or uncertainty as to the details of the work, because the regional officers were fully instructed prior to the commencement of any great movement as to the general plans of the higher command. They made their surveys, drew up their detailed plans, had them approved by their superior officers, thus insuring coördination, filed their requisitions for their necessary matériel and men, and were quite ready for the actual doing of the work when the moment arrived. Under such a system all that the individual and separate companies of engineers would have to do would be to report at the very last moment. The officers in command of those companies would then be given the plans and orders that they were to carry out. Friction, loss of time and uncertainty were avoided.

The lack of any practical value in or the reason for the size of an engineer regiment being fixed at a total of 1,700 officers and men soon became apparent to the American military authorities. In several instances

regiments were organized that differed widely from this establishment. The forestry regiment, for instance, as has been stated, included about 20,000 officers and men, the Nineteenth Engineers, one of the original nine, organized on the basis of thirty-three officers and 1,038 men with two battalions and six companies, finally grew into a unit of five battalions and fifteen companies, containing about 3,600 men. Other regiments, notably the Twenty-third and Twenty-ninth Engineers, were also expanded, retaining the regimental number and the regimental organization for purposes of administration only.

The above is not written in any spirit of criticism of what was done. When the United States declared war it had a very small army with no provision to meet the demands of a modern war. For the moment there was nothing else to do but to follow the standards then in force, and to modify them later when and how experience dictated. Radical changes were introduced. More would have followed had war continued. What the author wishes to emphasize is how it seems to him that engineers should be organized both in peace and war. As the result of two years' experience in active service, the author is of the belief that if the lessons of the war are to be learned and profit to be derived from them, provision should be made in the permanent establishment of the army for the practical training of officers and, if possible, some men in all the applications of engineering science, not merely in those few branches that only recently were considered as embracing military engineering. He further urges that the company rather than the regiment should be the unit of strength.

The organization of the French Fifth Engineers might well be taken as a type convenient for American needs in peace. During such time the usual regimental organization would be very convenient, providing as it does for an officer of years and experience to be at the head, one capable of seeing that the officers and men under him are

properly trained in their respective specialties. But should war again break out, for the possibility of war is always present, it is urged that the operation of engineering work in the field would best be entrusted to a series of regional engineers reporting either to the respective army commanders, or to some single authority with jurisdiction over the whole theatre of operations, whether in the Zone of the Advance or of the Rear. These engineers should be men of experience and matured judgment, which means that the posts should be filled with officers who would ordinarily have the rank of Lieutenant-Colonel or higher. To them the necessary surveying and designing staffs would, of course, be attached. On them should fall the burden of preparing all the detailed plans for whatever work is to be done, and so insure coördination. The units of the engineer troops should be the company and not the regiment, with the company commanded by an officer holding the rank of major, whose duties would be those of administration.

As to the size of these companies, for ordinary construction purposes in war, the limit of 250 men would seem to be well adapted, although for work in which specialists and experienced mechanics are needed, a company with one-half the size would probably be sufficient. These small companies should be housed either in trains or in motor vehicles, or so equipped as to be moved readily and quickly to whatever point their services might be needed. Such men would take care of all work that required special technical skill, the heavy labor being performed by specially organized but unskilled service battalions.

The same method of organization might also apply to division troops. There does not seem to be any particular reason why a fixed number of engineers should be assigned to every division. Some divisions require more than others. If the engineers were organized into companies, as many companies could be assigned to a

division as there were engineers available or as the work of the division required from time to time. If the company and not the regiment were the unit, the division engineer would be an officer on the staff of the division commander and ex officio the commanding officer of the troops. His functions would be exactly the same as the regional officers, namely, to lay out the engineering work for the division in conformity with the plans of the division commander and, after consultation with him, direct the commanding officers of the various companies assigned to the division to execute the work as planned. This would permit the division engineer to devote his whole time to the proper consideration of his engineering problems and relieve him of the burden of regimental administration. With the two tasks resting on the same man there is the danger of one or both being sacrificed. This scheme would also permit men to be selected for staff duty who were particularly well qualified for such service, rather than to take as a temporary staff officer the man who happened to be the senior officer of the attached engineer unit, a man who, while perhaps an excellent commander of troops in the field, might not have the qualifications for a competent staff officer.

This war was essentially an engineers' war. In other wars to come, science in its various applications will play a far greater rôle than it did even in the past one. In the war of 1917 the United States fortunately had the advantage of having two great allies who had worked out for themselves a solution of many of the engineering problems involved, and who gave the results of their experience freely and gladly to their new associate. In another war the United States may not be so well placed. We may suddenly find ourselves involved facing some great and powerful antagonist, and facing him without any more preparation than we had made prior to 1917. The time to prepare for such a contingency is now.

CHAPTER XXVI

ENGINEER ORGANIZATION AND ENGINEER WORK IN THE UNITED STATES

The preceding chapters give a picture of what engineers were required to do in France, a picture from which details have necessarily been omitted in order to reduce it to such a size that it might be viewed as a whole. That the results described could be achieved there was needed, in addition to the men who did the work of execution in the field, a well developed and smoothly running organization in the United States. The purpose of such an organization was to secure and train those who were to go overseas, to collect the plant and equipment that were required, and to construct the accommodations at home to house both the men and supplies prior to their shipment. By plant, equipment and accommodations there is meant not only those items that are intended for engineer use, but those for the whole army, the army that was held in the United States as well as the army of which the A. E. F. was composed. The extent of the plant and accommodations was enormous. The capacity of the accommodations, for instance, can best be measured in terms of cities because such dimensions as square yards or cubic feet were scales far too insignificant for the structures erected.

This organization came under the personal direction of the Chief of Engineers in Washington, Major-General William M. Black, and the work of preparation in the United States with which engineers were especially concerned may be summarized under two general headings:

1. The construction of camps, cantonments and miscellaneous structures by the Quartermaster Corps.
2. The activities of the Corps of Engineers, subdivided as follows:

    a. Construction of engineer depots and engineer shipping ports.
    b. Purchase and shipment of engineer matériel and equipment.
    c. Research work in connection with the perfection of old and the development of new engineer matériel, equipment, processes and methods.
    d. The organization, training, equipping and shipping abroad of engineer units:
        (a) Divisional and Corps Sapper Regiments.
        (b) Railway Units.
        (c) The Transportation Corps.
        (d) Units for Special Engineering Services.
        (e) Service Battalions (general laborers).
        (f) The Russian Railway Service Corps.

In the organization of the Department of Engineering of the army, known as the Corps of Engineers, there was a bureau called the General Engineer Depot, whose duty it had been, even prior to the war, to acquire the various equipment needed by the Corps of Engineers. The Depot had three subdivisions:

1. Engineer and Purchasing Department with general charge of the procurement and transportation of material into storage at various depots. The Purchasing Department had, as one of its subdivisions, and as a distinct organization a Research Department, composed of specialists and scientists engaged in the study of engineer problems connected with the duties of the Corps. This subsequently proved to be a most valuable piece of

machinery, as it furnished the foundation for the creation of a very extensive and highly useful bureau.

2. The Depot Department, with charge of accounting, storage and cantonment supplies. This department carried on investigations as to possible depot sites, leases of land, storehouses, piers and railway tracks, the preparation of plans for structures, the purchase of operating machinery and the development of plans for receiving, storing, shipping and accounting for property.

3. The business administration having charge of the office clerical force, contracts, legal and financial matters.

At the outbreak of the war in 1917 the Engineer Depot had a force of one officer and twenty civilians who were housed in a few rooms in Washington Barracks with a floor area of 3,500 square feet. By July the office accommodations covered 15,000 square feet and during the autumn grew to 25,000 square feet. In April, 1918, six portable buildings were erected for their use, giving 10,000 additional square feet of office space, and during October, 1918, the Depot organization was gathered together into one building, where it occupied 90,000 square feet of floor area. By this time the force had expanded to 1,454 people, of whom 182 were officers, 711 enlisted men and 561 civilians.

Much of the construction work in the United States came under the jurisdiction of the Quartermaster Corps as well as the Corps of Engineers, the former, through its own staff of engineers, caring for the erection of buildings and camps. Such work was, however, distinctly of an engineering character, so with no intention of ignoring the Quartermaster Corps and with every recognition of the exceedingly valuable service rendered and results accomplished by it, the work of construction in the United States will here be reviewed as a whole and treated as an achievement of engineering.

As was explained in the early part of this book, the

French and British Commissions made it clear to the authorities in Washington during April, 1917, that the most pressing and immediate need was for increased transportation facilities both in men and material. In this respect the army of the United States was quite lacking. It possessed neither men skilled in transportation nor any rolling stock or other equipment, except such small amounts as were used on local railways on various government reservations. The first step toward securing the men and procuring the equipment was taken when in April the Chief of Engineers called to his aid Mr. Samuel M. Felton, president of the Chicago Great Western Railroad, an engineer and railway executive of long and varied experience. During the threatened troubles along the Mexican border in 1916 Mr. Felton had acted as consulting engineer to the Chief of Engineers on railway matters.

Plans were at once prepared for the formation of a railway division of the Engineer Department in the army, at the head of which, in July, 1917, Mr. Felton was appointed, with a title of Director General of Railways. Subsequently on the appointment of a Director General of Transportation for the A. E. F. in France, Mr. Felton's title was changed to be Director General of Military Railways. In order to avoid confusion, Mr. Felton refused to accept military rank, but continued to act in a civilian capacity until all need for his services had passed, when he resigned and received the Distinguished Service Medal in recognition of what he had accomplished.

The Director General of Military Railways prepared the specifications and contracts for purchases of material, made the arrangements directly with the manufacturers, (except as to standard supplies, such as rails and small tools,) and then turned the agreements over to the General Engineer Depot for execution. In this way the newly

organized Railway Department coöperated without friction with the previously existing Depot organization.

The results obtained by the Director and the Engineer Depot were stupendous, and the figures of the value of the purchases, running as they did to hundreds of millions of dollars, would have been in any other period of the world's history beyond credibility.

The details of these purchases will be found at some length in the following chapter on "Statistics," but it is convenient to point out here that between July, 1917, and November 11, 1918, the total value of all orders placed by the General Engineer Depot for Engineer material and supplies was $746,242,507, with an approximate tonnage of such supplies of 4,567,800.

These expenditures and tonnage were quite exclusive of those due to purchases made in the ordinary course of work for items not connected with the war, such as the normal construction and maintenance of lighthouses, sea-coast defenses, and rivers and harbors in the United States.

Although contracts for the above purchases were made, as a matter of fact all the contracts were not fully executed owing to the termination of hostilities, and consequently the full complement was neither required nor called for. However, of the above-mentioned amount, 1,506,000 tons of engineer material were actually shipped to the A. E. F. and 160,000 tons were at the ports waiting transportation when the Armistice was signed. Of the grand total the value of railway material alone, including rolling stock, rails, etc., amounted to $526,000,000 for the Expeditionary Force, not including the value of similar material used in connection with various war industries in the United States.

It is not without interest to note that the average cost per ton for all material sent overseas was $168.00; taking the average of everything from tenpenny nails to electric

locomotives, the average cost of the railway equipment of all kinds was $155.00 per ton, of automobile equipment $800.00 per ton, and of general machinery $400.00.

Of the purchases of railway equipment the principal items were the following:

Standard gauge locomotives......	3,750
Light railway locomotives........	1,501
Standard gauge cars.............	91,519
Light railway cars...............	8,530
Rails, tons	749,345

The figures of the details were on the same great scale. To mention but a few items, there were actually shipped overseas or used in the United States:

Trucks of various kinds........	7,137
Portable buildings	2,082
Boilers	6,006
Dump cars	3,504
Screw posts for wire entanglements......................	2,308,225
Nails, tons	10,612
Shovels, various kinds.........	2,923,936
Picks	1,731,913
Barbed wire, tons..............	131,802
Paint, gallons	1,000,000
Saws, various kinds............	399,877

Eighty-three per cent of the tonnage sent abroad passed through the ports of New York and Norfolk, with Norfolk leading.

The above figures of purchases are quite exclusive of materials purchased abroad. No less than 1,800,000 tons of miscellaneous engineering supplies, costing $205,000,000, were thus purchased, chiefly in France, England and Switzerland, about sixty per cent being furnished by France.

The activities of the Director General of Military Rail-

ways were not confined wholly to the acquisition of inanimate objects, but covered also the human element. During 1917 the Director supervised the organization, from among the railway systems in the United States, of eleven regiments of engineers, aggregating 506 officers and 12,765 men. Before the war ended 41 special railway units had been sent abroad, consisting of 1,314 officers and 53,352 men.

All the above force was sent to the western front. At the beginning of the war the War Department appointed a Commission under Mr. John F. Stevens, formerly Chief Engineer of the Panama Canal, as chairman, and sent them to Russia to investigate the railway situation in that country. Later, at the request of Mr. Stevens, the Director organized a railway unit to go to Russia, to be paid by the Russian Government. Although the members of the unit did not form a part of the army of the United States they were given nominal military rank.

This organization, which sailed from San Francisco on November 11, 1919, consisted of 1 Colonel, George H. Emerson; 5 Lieutenant-Colonels, 14 Majors, 22 Captains, 80 First Lieutenants, 166 Second Lieutenants, 32 Interpreters, 16 Mechanics and 1 Medical Officer, a total of 337 persons, who, in spite of the many difficulties and disappointments, finally succeeded in rendering valuable services in connection with the rehabilitation and operation of Russian railways.

There was one field of engineering activity which was less commercial than buying locomotives by the gross or the whole output for months of various factories. Though it called for fewer men than were required to run even the contract department, it produced tangible results whose tremendous value was beginning to be clearly apparent when hostilities ceased, and which before that had already won official approval. This was the field of experimentation and investigation.

As was mentioned above, there was in the Purchasing Department of the Engineer Depot, a Bureau of Research. Prior to the war its functions were limited, but after the commencement of war it quickly became a vast productive laboratory. There are few more fascinating stories than its record of study and investigation in the fields of chemistry, physics and electricity, investigations that involved long and tedious laboratory experiments calling for the highest technical skill and unlimited patience. Among other accomplishments, the Bureau of Research examined into the composition and methods of manufacture of toxic gases and gas defense measures, it designed the delicate but highly accurate range sound detectors and other instruments of precision, as well as mobile machine shops, portable pile drivers, field map-printing plants and photographic apparatus for various uses. It standardized the requirements of paints and varnishes, produced standard specifications for mechanical rubber goods, pointed out how the enamel coating on hardware and kitchen utensils could be improved, studied the rating of internal combustion engines, conducted a series of experiments which finally resulted in the improvement of certain high explosives and the designing of a new machine for exploding detonating caps.

The most substantial result of the work done by the Bureau of Research as measured by output was in the production of toxic gas. At the beginning of the war the manufacturing capacity of gas of this character in the United States was practically negligible, there being but little commercial demand for it. The chemists were without experience, but thanks to the new work done by them, the Bureau of Research was able to convince the Government that it was sound policy to erect a manufacturing plant of its own where gases could be manufactured on a huge scale. In addition the Bureau assisted in

encouraging various private industries throughout the country to produce gases in quantity.

The plant that was erected was the Edgewood Arsenal, near Aberdeen, Md. Before the war came to an end 558 buildings had been constructed on the grounds, including 86 cantonment structures capable of housing 4,000 men. There were hospitals, separate buildings for the welfare work and three power houses with a total installed potentiality of 526 kw. There were 21 miles of standard gauge railway, 15 miles of narrow gauge railway, nearly 15 miles of highways, and 2 water systems with a combined capacity of 3,500,000 gallons daily. At one time no fewer than 7,400 troops were at work because, on account of the dangerous character of the operations, it was decided to mobilize the forces so as to put them under army discipline.

At the conclusion of the war the gas industry had grown from approximately nothing to a total actual output capacity of more than 6,000 tons of lethal gases per month.

As indicating how far the activities of this Bureau reached out even to small matters, a certain concern had been accustomed to produce before the war about 15,000 watch pocket compasses per year. Their production had to be so speeded up so as to have them turn out no fewer than 10,000 of these compasses each week in order that the officers in the field might be supplied. This was accomplished through the insistence and on the suggestions of the Bureau of Research.

Then there was the great housing and building programme executed by the engineers of the Quartermaster Corps. The magnitude of the problem that confronted the engineers cannot be described in better terms than those in the letter of instruction of the Committee on the Emergency Construction of Buildings addressed to the officers in charge.

"In sixteen weeks you are expected to have suitable quarters ready for the training of 1,100,000 men.

"You must be building in 32 places at once. Most of the sites for the cantonments have not yet been chosen. When they have been fixed a group of engineering problems of first importance must be settled. The water supply for each camp must be carefully studied. Failure to supply abundance of pure water may jeopardize the whole undertaking. Proper sewerage must be provided if the danger of epidemic is to be forestalled. Heating, lighting, refrigerating and laundry facilities must be furnished. The solution of these engineering problems will be different in every locality."

What the above figures mean is that within a period of less than four months there were being erected building accommodations sufficient to house the combined populations of Buffalo, N. Y.; Washington, D. C., and San Francisco, Cal.

All told there were 44 of these camps erected, with accommodations for a total of 1,695,691 men at an approximate cost of $373,466,184.00.

The lumber that was ordered for these camps has been computed as being sufficient to have made a board-walk twelve feet wide and one inch thick reaching from the earth to the moon and half way back again.

To house the material and supplies needed for the army at home and overseas, until such time as they were called for, or sent abroad, great storehouses were erected, and terminal projects were designed and carried to execution with almost feverish speed in order that freight intended for the A. E. F. might be loaded on board ship without delay and in such manner as to reduce port congestion to the minimum. With the existing scarcity of ocean tonnage it was of the most pressing importance that vessels be not held in the harbor.

The new terminal facilities for ships that were created,

exclusive of those in existence before the war, were equivalent to those of a wharf eight miles long with berthing capacity for 65 ships. The warehouses erected at the ocean ports and depots in the interior contained no less than 690 acres, or more than one square mile, of covered storage space provided by buildings built of reinforced concrete. So extensive were these buildings that the material entering into their construction would have sufficed for a storehouse 70 feet wide and as long as from New York to Philadelphia. To serve the terminals and other depots there were constructed 650 miles of railways and 1,000 miles of concrete roadways.

At Brooklyn, in the Port of New York, two 8-story reinforced concrete warehouses were undertaken, each of which was 980 feet long. One of them was 200 feet wide and the other 300 feet wide, with a combined capacity to store 700,000 tons of supplies or the equivalent of about 100 ship loads. The car tracks of this single installation were sufficient to hold 1,300 cars at one time.

This was the largest single unit, but other big terminal plants were erected at Boston, Norfolk and New Orleans. The combined terminals and interior storage depots had an aggregate floor area of 29,861,514 square feet, and cost approximately $169,456,537.00

Then there were hospitals of which 42 were erected with a total capacity stated in beds of 59,045 and at a cost of $28,957,223.00.

The total cost of various buildings erected and equipped by the War Department in the United States exceeded $1,000,000,000. The best general picture of what this unthinkable figure means is given in the official report on America's Munitions:

"We can gain a picture of the size of this construction by considering the building records of the United States. In this country there are about 150 cities large enough and ambitious enough to keep annual building statistics

as the indices of their prosperity. In these cities, whose populations range in size from that of New York down to those of communities of 20,000 or 25,000 inhabitants, dwell nearly a quarter of all the Americans. They are metropolitans, the people who demand most of the builder for their comfort and luxury. Yet in no one year had the building construction in these 150 largest American cities combined approached in amount within $250,000,000 of the cost of our military construction undertaken during the war.''

To design, direct and supervise the above construction there was created a special bureau known as the Construction Division.

The engineer officers had other problems to solve than those of laying out camps, constructing terminal storehouses, designing searchlights or conducting intricate chemical investigations. There were such very practical things requiring attention as sending away the supplies after they had reached the ports. Even this problem necessitated special study and called for many innovations from ordinary standard practice, because the supplies had to be loaded on ships, not merely as so much tonnage to be sent away on export, but as precious cargo that would be received and disposed of at the port of entry under peculiarly novel and abnormal conditions. The manner in which locomotives were packed in the holds of vessels so as to give the minimum of inconvenience when discharging them in France is one illustration of how the seemingly impossible was accomplished.

Ordinarily locomotives are shipped " knocked down "; that is, the boilers, frames, trucks, operating mechanism and other parts are loaded separately, and when received at destination the dismembered pieces are placed on cars, sent to some erecting shop and there assembled. Owing to the conditions that existed in France, this

arrangement was very inconvenient and costly in time, labor and space. The discharge of a bulky article like a locomotive boiler, which demanded that a special car be ready to receive it from the unloading crane, seriously disturbed the even flow of the mass of freight consisting chiefly of boxes of food stuffs, clothing or ammunition which were deposited in piles on the wharf and thence loaded into cars or trucked to storehouses. Then after the boiler and other heavy parts were securely placed on cars, they had to be drawn to some locomotive shop, unloaded and set up. All this involved much rehandling, delayed unloading, caused confusion, created traffic for a terminal railway already badly congested, threw work on shops that were short of skilled mechanics, and above all delayed the discharge of the ship, a loss of time that was very precious.

The British, after experiencing similar troubles, placed locomotives on barges without any attempt to dismantle them, and thus sent them from England to France, a not very difficult feat because the water journey was so short. But the American Director General of Transportation saw the possibilities contained in the idea and requested that our own locomotives be loaded on board ship, "ready-to-run," so that when unloaded they could be set directly on the rails and hauled away. This was a radically novel suggestion, involving all manner of mechanical difficulties seemingly insuperable, when there are called to mind the great weight and awkward outlines of a complete locomotive. The form of locomotives is so irregular as almost to defy their stowing in the deep confined hold of a ship, with freight below and above, and yet all so securely packed as to resist the pitching and rolling motion of a ship in an Atlantic storm. But the engineers in the United States succeeded in doing it as they solved many other new problems. Only the smoke-stack and drivers' cab were removed, everything else

being left in place. The levers and the other operating devices attached to the boiler-head were boxed in to prevent damage. Then the engines and their tenders, with all wheels attached, were picked up bodily by large cranes and lowered into the hold of a waiting steamer, where they rested on stout timbers. The spaces between them were filled with small packages such as boxes or bales to keep them from moving. On arrival they were again handled by a crane, set on the rails, run off on their own wheels to some small shop, where it was a simple job to attach the stack and cab. Then all that remained was to put on board coal, water and oil, and another hauling unit was ready to carry men or ammunition to the front. The illustration at the beginning of this book shows a large locomotive being loaded on board ship in the port of New York.

The figures are at hand showing the saving that resulted from shipping locomotives whole. St. Nazaire was selected, in the early days of American participation, as the port through which locomotives would be shipped, as unloading cranes and the needed special facilities for handling bulky weights were installed there. But it was found impossible to take the locomotive parts as they came off the steamers, crated or boxed, directly into the shops, as there was barely room to care for the erecting. Furthermore, it was frequently necessary to unload almost entirely a boat before all the parts of a complete locomotive were found. As each locomotive was shipped in thirty-two different crates or boxes, some of which weighed over 30,000 pounds, and as many as forty locomotives arrived in a single ship, it will be readily seen that it was necessary to have a large storage yard in which to uncrate, sort and store by locomotive numbers the parts of same. This yard the engineers built, involving much filling, and until this was in operation, it was necessary to utilize dock space, shop space and, in fact,

every available space for the unboxing and sorting of locomotive parts.

After the scattered members of a locomotive had been collected and brought to the shop, twenty-six hours of shop time were required to erect them into a complete machine. When locomotives were received minus only stack and cab, the time needed to prepare one for service was reduced to six hours — or eight at the maximum. In addition there were the benefits of a great saving in wharf space and the hastening of the discharge of vessels.

The personnel of engineer units was selected as far as possible from men with mechanical experience, but the efficient engineer recruits had to be instructed in military duties and in certain phases of military engineering with which they were not familiar. During the first six months of the war special instructors were detailed by the French and British to give training to American recruits at the camps in the United States in the laying out and digging of trenches, the excavating of dugouts, the handling of grenades and the doing of the many innovations produced by the war. Later as American officers obtained first hand experience in Europe, they were sent back to serve as engineer instructors and relieve our allies from this duty.

It was a great army of engineers that went to France, but they would have been helpless without the organization at home. Those that went overseas had the reward of excitement and field activity. Those that remained did other work at the desk, in the designing room or laboratory, largely unnoticed and rarely seen. It was not their good fortune to share with the others in the danger and glory of battle, but to them there is due quite as much credit for the final success as to those who went over the top. Both were equally members of the Corps of Engineers of the Army of the United States.

Remarkable as were the actual achievements in organ-

izing, equipping and sending troops to France, and the development and perfection of a great variety of engineering and scientific equipment methods and processes, they were relatively insignificant as compared with what undoubtedly would have been accomplished had the war continued a little longer. The necessary preliminary work had all been done, cantonments, hospitals, warehouses were all erected and in splendid working order both in the United States and in France. Industrial plants had been tuned up to produce every conceivable article needed in modern warfare, in vast quantities and with incredible speed. The many months of patient scientific research work had resulted in the perfection of new methods and new devices which in a short time could have supplied all the articles needed in such quantities as to have still further revolutionized modern methods of warfare, while the fruits of other theoretical investigations were on the very point of receiving practical application.

CHAPTER XXVII

STATISTICS

The dimensions of the war, regarded from any point of view and in every detail except the one of time, cannot be measured by any comparison with similar dimensions of other wars. The statistical branch of the War Department of the United States government has issued a report, entitled "The War With Germany," covering the main features not only so far as they relate to the United States, but to some extent as they relate to the allied and enemy countries as well. This report gives probably as good a measure of the size of the war as any report that can be produced. So valuable are these figures, so striking are the deductions that, with the consent of the statistical branch of the General Staff, the following condensed extracts have been made as showing so far as figures can, the organization, equipping and supplying of the army, its transportation to and from France, the results accomplished and the cost in money, materials and the most important item of all, men.

The armed forces of the United States during the war, April 6, 1917, to November 11, 1918, numbered approximately 4,800,000. About 4,000,000 served in the Army, the Navy, the Marine Corps, and the remaining 800,000 in the other services. Approximately five out of every 100 American citizens took up arms in defense of their country.

The number of men serving in the Army and Navy of the Northern States during the Civil war was 2,400,000, or about ten out of every 100 inhabitants. Comparing the effort of the United States in the war with Germany

with that of the Northern States in the Civil war, we see that the entire United States raised actually twice as many men as the Northern States raised in the Civil war, but proportionately to the population only half as many. It cost twenty times as much to recruit the 2,400,000 men who fought on the Northern side during the Civil war as it did to recruit the 4,800,000 men who were raised to fight against Germany, or fifty times as much for each soldier, sailor, and marine.

SIZE OF THE ARMY ON FIRST OF EACH MONTH DURING THE WAR WITH GERMANY

	IN THE UNITED STATES AND POSSESSIONS	AMERICAN EXPEDITIONARY FORCE	TOTAL
1917			
April..........	200,000	....	200,000
May..........	290,000	....	290,000
June..........	390,000	....	390,000
July..........	480,000	20,000	500,000
August........	516,000	35,000	551,000
September.....	646,000	45,000	691,000
October.......	883,000	65,000	948,000
November.....	996,000	104,000	1,100,000
December.....	1,060,000	129,000	1,189,000
1918			
January.......	1,149,000	176,000	1,325,000
February......	1,257,000	225,000	1,482,000
March.........	1,386,000	253,000	1,639,000
April..........	1,476,000	320,000	1,796,000
May..........	1,529,000	424,000	1,953,000
June..........	1,390,000	722,000	2,112,000
July..........	1,384,000	996,000	2,380,000
August........	1,365,000	1,293,000	2,658,000
September.....	1,422,000	1,579,000	3,001,000
October.......	1,590,000	1,843,000	3,433,000
November.....	1,663,000	1,971,000	3,634,000
December.....	1,679,000	1,944,000	3,623,000
1919			
January.......	1,163,000	1,837,000	3,000,000
February......	914,000	1,710,000	2,624,000
March	761,000	1,562,000	2,323,000
April..........	680,000	1,376,000	2,056,000
May	666,000	1,088,000	1,754,000
June..........	578,000	730,000	1,308,000
July..........	579,000	357,000	936,000
August........	442,000	133,000	575,000

SOURCES OF THE ARMY

	APRIL, 1917	PER CENT	TOTAL FOR WAR	PER CENT
Regular Army	133,000	67%	527,000	13%
National Guard...........	67,000	33%	382,000	10%
National Army...........	....	.....	3,091,000	77%
Grand Totals.............	200,000	100%	4,000,000	100%

NOTE.—The round total of 4,000,000 in this table covers all inductions into the army. The difference between this figure and that of 3,634,000 for November, 1919, in the preceding table, is accounted for by deaths and discharges previous to the Armistice.

PERCENTAGE OF DRAFTED MEN PASSING PHYSICAL EXAMINATIONS BY STATES

70% to 80%		
Arkansas	Minnesota	Oklahoma
Iowa	Nebraska	South Dakota
Kansas	New Mexico	Texas
Kentucky	North Dakota	Wyoming
65% to 69%		
Alabama	Louisiana	Montana
Florida	Maryland	North Carolina
Illinois	Mississipp	Ohio
Indiana	Missouri	West Virginia
		Wisconsin
60% to 64%		
Georgia	New Jersey	South Carolina
Idaho	Oregon	Tennessee
Nevada	Pennsylvania	Utah
		Virginia
50% to 59%		
Arizona	Delaware	New Hampshire
California	Maine	New York
Colorado	Massachuetts	Rhode Island
Connecticut	Michigan	Vermont
		Washington

OFFICERS COMMISSIONED FOR LINE DUTY FROM TRAINING CAMPS BY SERVICES

BRANCH OF SERVICE	NUMBER COMMISSIONED	PER CENT
Infantry	48,968	60.7
Field Artillery	20,291	25.2
Quartermaster	3,067	3.8
Coast Artillery	2,063	2.6
Cavalry	2,032	2.5
Engineer	1,966	2.4
Signal	1,262	1.6
Ordnance	767	1.0
Statistical	152	.2
Total	80,568	100.0

SOURCES OF THE COMMISSIONED PERSONNEL

SOURCE	NUMBER	PER CENT
Officers' Training Camps........	96,000	48
Physicians....................	42,000	21
Civil Life.....................	26,000	13
Enlisted Men.................	16,000	8
National Guard...............	12,000	6
Regular Army.................	6,000	3
Chaplains....................	2,000	1
Total....................	200,000	100

Training of the Army

The American soldier who fought in France had on the average six months' training in the United States, two months' training overseas before entering the line, and one month in a quiet sector before going into battle.

Two out of every three American soldiers who reached France went into battle. The number that saw active service in the front line was 1,390,000 out of a total of 2,084,000 who debarked at French ports. In this total are included the men, amounting to nearly 400,000, who reached France in September, October and November, 1918, within less than three months of the signing of the armistice, and who had not completed their full period of training. Some of these troops, nevertheless, saw active service.

The greater proportion of our overseas forces received their training in infantry divisions which are our typical combat units, and consisted of about 1,000 officers and 27,000 enlisted men. Forty-two such divisions were sent to France, besides several hundred thousand supplementary artillery service, and supply troops.

American divisions were composed, when at full strength, of 28,000 officers and men and were the largest divisions of any army on the western front. The British

divisions contained in actuality about 15,000 each, while the French and the German divisions contained only about 12,000 each.

The training of our army in the United States was assisted by nearly 800 specially skilled French and British officers and noncommissioned officers, who rendered invaluable service as instructors in the training camps.

More than two-thirds of our line officers were graduates of the officers' training camps.

Transportation of the Army

More than 2,000,000 American soldiers were transported to France in the nineteen months during which we took part in the war. Half a million went over in the first thirteen months, and a million and a half in the last six months. It was not until December, 1917, that the sailings approximated 50,000 a month. The following table shows the number sailing each month for France in 1918, and for America between the signing of the armistice and June 30, 1919.

MEN SAILING FROM AMERICA TO FRANCE		MEN SAILING FROM FRANCE TO AMERICA	
1917—9 months (approx.)	200,609		
1918		1918	
January	47,833	November	26,245
February	49,110	December	99,111
March	84,889	1919	
April	118,642	January	115,382
May	245,945	February	181,751
June	278,664	March	212,899
July	306,350	April	290,377
August	285,974	May	333,303
September	257,457	June	364,163
October	180,326		
November	30,201		
Total (19 mos.)	2,086,000	Total (8 mos.)	1,623,231
Average per mo	110,000	Average per mo	203,000

Growth of the Transport Fleet

To convey this great army to France, to keep it supplied with food, clothing, arms, ammunition and other requisites for effective service, and to bring the men home after the war, demanded the creation of an adequate transport fleet at a time when the world was experiencing its most acute shortage of ocean tonnage. The development of this fleet is shown in the following table, which gives its size in dead-weight tons on the first of each month.

TRANSATLANTIC FLEET IN DEAD-WEIGHT TONS

BY MONTHS	TRANSPORTS	CARGO SHIPS	TOTAL
1917			
July 1			94,000
August 1			131,000
Sept. 1			177,000
Oct. 1	59,000	229,000	288,000
Nov. 1	168,000	297,000	465,000
Dec. 1	195,000	467,000	662,000
1918			
Jan. 1	243,000	543,000	786,000
Feb. 1	243,000	620,000	863,000
Mar. 1	250,000	718,000	968,000
Apr. 1	274,000	926,000	1,200,000
May 1	372,000	1,066,000	1,438,000
June 1	395,000	1,184,000	1,579,000
July 1	403,000	1,350,000	1,753,000
Aug. 1	394,000	1,485,000	1,879,000
Sept. 1	401,000	1,633,000	2,034,000
Oct. 1	397,000	1,933,000	2,330,000
Nov. 1	390,000	2,310,000	2,700,000
Dec. 1	493,000	2,753,000	3,246,000
1919			
Jan. 1	681,000	2,567,000	3,248,000
Feb. 1	797,000	2,047,000	2,844,000
Mar. 1	878,000	1,713,000	2,591,000
Apr. 1	928,000	1,198,000	2,126,000
May 1	1,087,000	752,000	1,839,000

Coöperation of Allies

Of the 2,086,000 American troops that sailed to France, 927,000 went in American vessels, while 1,027,000 were carried in British transports, 20,000 in Russian

ships under British control, 65,000 in Italian, and 47,000 in French ships. To put it another way, of every 100 soldiers who went overseas, forty-nine sailed in British ships, forty-five in American ships, three in Italian ships, two in French ships, and one in Russian shipping under British control.

The American transports carried more men in proportion to tonnage than those of the coöperating nations. This was due to two factors, our transports exceeded those of the Allies in the speed of their turnarounds; and, under the pressure of the critical situation on the western front, ways were devised to increase the loading of our own transports by as much as fifty per cent.

PORTS OF EMBARKATION AND DEBARKATION

AMERICAN PORTS	SAILED	ENGLISH PORTS		ARRIVED
Quebec.........	11,000	Glasgow...........	45,000	
Montreal.......	34,000	Manchester........	4,000	
St. Johns.......	1,000	Liverpool..........	844,000	
Halifax........	5,000	Bristol Ports	11,000	
Portland.......	6,000	Falmouth..........	1,000	
Boston.........	46,000	Plymouth.........	1,000	
New York......	1,656,000	Southampton......	57,000	
Philadelphia....	35,000	London...........	62,000	1,025 000
Baltimore......	4,000			
Newport News..	288,000	FRENCH PORTS		
		Le Havre..........	13,000	
		Brest..............	791,000	
		St. Nazaire.........	198,000	
		La Pallice.........	4,000	
		Bordeaux..........	50,000	
		Marseille	1,000	1,057,000
		ITALIAN PORTS		2,000
Total..........	2,086,000			2,084,000

NOTE:—The difference of 2,000 between those who sailed from American and those who landed in France is accounted for in part by deaths in transit and in part by those who sailed, but, for one reason or another, were not landed.

ARMY CARGO SHIPPED TO FRANCE TO APRIL 30, 1919

SHIPMENTS BY MONTHS		DISTRIBUTION		PER CENT
	Short Tons	Branch of Service	Short Tons	Per cent
1917				
June	16,000	Quartermaster	3,606,000	48.39
July	12,000	Engineer	1,506,000	20.21
August	19,000	Ordnance	1,189,000	15.96
September	53,000	Food Relief	285,000	3.82
October	115,000	Motor Transport	214,000	2.87
November	78,000	French Material	208,000	2.79
December	180,000	Signal Corps	121,000	1.62
		Medical	111,000	1.49
1918		Aviation	61,000	.82
January	122,000	Red Cross	60,000	.81
February	228,000	Y. M. C. A.	45,000	.60
March	289,000	Miscellaneous	35,000	.47
April	373,000	Chemical Warfare	11,000	.15
May	450,000			
June	425,000			
July	536,000			
August	572,000			
September	681,000			
October	750,000			
Novenber	829,000			
December	587,000			
1919				
January	363,000			
February	266,000			
March	298,000			
April	211,000			
Total (23 months)	7,453,000		7,452,000	100.0

NOTE:—The discrepancy of 1,000 tons in these totals is very small considering that only round numbers are used in these estimates.

America's Part in the Actual Fighting

THIRTEEN MAJOR OPERATIONS IN WHICH AMERICANS PARTICIPATED

OPERATION	APPROXIMATE NUMBER OF AMERICANS ENGAGED
West front—campaign of 1917:	
Cambrai, Nov. to Dec. 4	2,500
West front—campaign of 1918:	
German offensive, March 21 to July 18	....
Somme, March 21 to April 6	2,200
Lys, April 9 to 27	2,500
Aisne, May 27 to June 5	27,500
Noyon-Montdidier, June 9 to 15	27,000
Champagne, Marne, July 15 to 18	85,000
Allied Offensives, July 18 to Nov. 11:	
Aisne-Marne, July 18 to Aug. 6	270,000
Somme, Aug. 8 to Nov. 11	54,000
Oise-Aisne, Aug. 18 to Nov. 11	85,000
Ypres-Lys, Aug. 19 to Nov. 11	108,000
St. Mihiel, Sept. 12 to 16	550,000
Meuse-Argonne, Sept. 20 to Nov. 11	1,200,000
Italian front—campaign of 1918:	
Vittorio-Veneto, Oct. 24 to Nov. 4	1,200

AMERICAN DATA FOR THE MEUSE-ARGONNE BATTLE

Days of battle	47
American troops engaged	1,200,000
Guns employed in attack	2,417
Rounds of artillery ammunition fired	4,214,000
Airplanes used	840
Tons of explosives dropped by planes on enemy lines	100
Tanks used	324
Miles of penetration of enemy line, maximum	34
Square kilometers of territory taken	1,550
Villages and towns liberated	150
Prisoners captured	16,059
Artillery pieces captured	468
Machine guns captured	2,864
Trench mortars captured	177
American casualties	120,000

The actual weight of the ammunition fired in this battle was greater than that used by the Union forces during the entire Civil war.

In the preceding Battle of St. Mihiel, 550,000 Americans were engaged, as compared with about 100,000 on the Northern side in the Battle of Gettysburg in the Civil war. At the Battle of St. Mihiel the artillery fired more than 1,000,000 shells in four hours, which is the most intense concentration of artillery fire recorded in history.

American Artillery in France

The most significant facts about our artillery are presented in the following table, which takes into account only light and heavy field artillery, and does not include either the small 37 mm. guns or the trench mortars.

SUMMARY

Total pieces of artillery received to November 11, 1918	3,499
Number of American manufactured	477
American made pieces used in battle	130
Artillery on firing line	2,251
Rounds of ammunition expended	8,850,000
Rounds of American made ammunition expended	208,327
Rounds of American made ammunition expended in battle	8,400

The facts shown in the above table may be paraphrased with approximate accuracy by saying that the American army in France had in round numbers 3,500 pieces of artillery, of which less than 500 were made in America, and that we used on the firing line 2,250 pieces, of which only 130 (less than six per cent) were made in America.

Note by the Author: The guns that were used were of French manufacture. As the American army was intended to coöperate largely with the French, it was deemed advisable to equip it with French artillery. This the French government undertook to do provided America sent the steel and other raw material. It was greatly to the credit of France that after nearly four

years of war she was still able to produce a surplus of manufactured equipment if only the material were furnished.

TOXIC GASES MANUFACTURED IN 1918—IN TONS (2,000 lbs.)

	MANUFACTURED DURING MONTH	TOTAL TO DATE
January	10	10
February	61	71
March	211	282
April	399	681
May	697	1,378
June	993	2,371
July	1,351	3,722
August	1,548	5,270
September	1,911	7,181
October	2,726	9,907
November	910	10,817

AVIATION

FLYING OFFICERS IN THE ARMY—BY MONTHS

	IN U. S.	IN A. E. F.	TOTAL
1919			
April	75	....	75
May	105	....	105
June	139	....	139
July	199	....	199
August	203	26	229
September	270	31	301
October	572	31	603
November	831	45	876
December	989	157	1,146
1918			
January	1,576	321	1,897
February	1,712	485	2,197
March	2,248	650	2,898
April	2,563	1,800	4,363
May	3,841	2,200	6,041
June	3,944	2,840	6,784
July	4,974	2,692	7,666
August	5,916	3,060	8,976
September	6,306	3,450	9,756
October	6,171	4,252	10,423
November	7,118	4,307	11,425

PRODUCTION OF SERVICE PLANES—TO END OF EACH MONTH

	FROM FOREIGN SOURCES	FROM AMERICAN SOURCES	TOTAL
1917			
September	6	....	6
October	75	....	75
November	258	....	258
December	266	....	266
1918			
January	304	....	304
February	402	9	411
March	552	13	565
April	695	30	725
May	969	196	1,165
June	1,345	541	1,886
July	1,975	1,028	3,003
August	2,536	1,184	3,720
September	3,047	1,892	4,939
October	3,483	3,014	6,497
November	3,800	4,089	7,889

SERVICE PLANES SENT TO ZONE OF ADVANCE BY END OF EACH MONTH

	FROM FOREIGN SOURCES	FROM AMERICAN SOURCES	TOTAL
1917			
October	1	....	1
November	0	....	0
December	3	....	3
1918			
January	4	....	4
February	22	....	22
March	119	....	119
April	180	....	180
May	376	....	376
June	476	....	476
July	810	34	844
August	1,205	178	1,383
September	1,722	518	2,240
October	1,938	627	2,565
November	2,031	667	2,698

NOTE.—Nine-tenths of the airplanes received from foreign sources were of French manufacture.

To summarize, of the 2,698 planes sent to the Zone of the Advance for American aviators, 667, or less than one-fourth, were of American manufacture.

American air squadrons took important parts in the battles of Château-Thierry, St. Mihiel, and the Meuse-Argonne. They brought down in combat 755 enemy planes, while their own losses were only 357 planes.

Casualties

BATTLE DEATHS IN THE ARMIES ENGAGED IN THE WAR

Russia	1,700,000
Germany	1,600,000
France	1,385,300
Great Britain	900,000
Austria	800,000
Italy	364,000
Turkey	250,000
Serbia and Montenegro	125,000
Belgium	102,000
Roumania	100,000
Bulgaria	100,000
United States	50,300
Greece	7,000
Portugal	2,000
Total	7,485,600

Of every 100 American soldiers and sailors, two were killed or died of disease. Among the other great nations between twenty and twenty-five in each 100 called to the colors were killed or died.

The total battle deaths in this war were greater than all the deaths in all the wars for more than 100 years previous. From 1793 to 1914 the total deaths in war may be safely estimated at something under 6,000,000. Battle deaths from 1914 to 1918 totaled about 7,500,000.

American Casualties in the War

Wounded, Prisoners and Missing

For every man who was killed in battle, six others were wounded, taken prisoner, or reported missing. The total

battle casualties in the expeditionary forces are shown in the following table. The number who died of wounds was only seven per cent as large as the number who were wounded. The hospital records show that about eighty-five per cent of the men sent to hospitals on account of injuries were returned to duty. About half the wounded were reported as slightly wounded and many of them would not have been recorded as casualties in previous wars.

BATTLE CASUALTIES IN THE AMERICAN EXPEDITIONARY FORCE

Killed in action	35,560	
Died of Wounds	14,720	
Total dead		50,280
Wounded severely	90,830	
Wounded slightly	80,480	
Wounded, degree undetermined	34,380	
Total wounded		205,690
Missing in action (August 1, 1919)		46
Taken prisoner		4,480
Grand Total		206,496

CAUSES OF DEATH IN THE AMERICAN ARMY

		NUMBER	PER CENT
Killed in battle or died of wounds, A. E. F		50,280	43
Died of disease:			
In A. E. F	21,410		
In U. S	36,050		
Total by disease		57,460	50
Deaths from other causes A. E. F		7,920	7
Total		115,660	100%

DISEASE AND BATTLE DEATHS IN AMERICAN ARMY IN FOUR WARS

The figures give the number of deaths for each 1,000 troops.

	DISEASE	BATTLE	TOTAL
Mexican War, 1846-48	110	15	125
Civil War (North) 1861-65	65	33	98
Spanish War 1898	26	5	31
War with Germany:			
A. E. F. to Nov. 11, 1918	19	53	72
Total forces to May 1, 1919	15	13	28

DEATHS BY DISEASES—PRINCIPAL CAUSES

Both in the A. E. F. and United States for Entire Army, Expressed in Percentages

Pneumonia	83.6
Meningitis	4.1
Tuberculosis	2.3
Empyema	1.1
Septicemia	.6
Brights' Disease	.5
Typhoid	.5
Peritonitis	.5
Appendicitis	.4
Organic Heart Diseases	.4
Scarlet Fever	.3
Measles	.3
Other	5.5
Total	100.0

War Expenditures

For a period of twenty-five months from April, 1917, through April, 1919, the war cost the United States considerably more than $1,000,000 an hour, or $21,850,000,000 exclusive of nearly $10,000,000,000 loaned to the Allies.

This amount is twenty times the pre-war national debt. It is nearly enough to pay the entire costs of our Government from 1791 to the outbreak of the European war. The expenditures in this war were sufficient to have car-

ried on the Revolutionary war continuously for more than a thousand years at the rate of expenditure which that war actually involved.

During the first three months war expenditures were at the rate of $2,000,000 a day. During the next year they averaged more than $22,000,000 a day. For the final ten months of the period the daily costs reached the enormous total of more than $44,000,000.

MY PURCHASES OF FOUR ARTICLES IN 1918 COMPARED WITH TOTAL PRODUCTION IN 1914

ARTICLE	PURCHASED, 1918	PRODUCED, 1914
Blankets	18,000,000	8,000,000
Wool gloves	13,000,000	30,000,000
Wool socks	96,000,000	61,000,000
Shoes	19,000,000	98,000,000

Some International Comparisons

TOTAL WAR EXPENSES OF PRINCIPAL NATIONS.

(Estimated to April 30th, 1919.)

Great Britain and Dominions	$38,000,000,000
France	26,000,000,000
United States	22,000,000,000
Russia	18,000,000,000
Italy	13,000,000,000
Belgium, Roumania, Portugal, Jugo-Slavia	5,000,000,000
Japan and Greece	1,000,000,000
Total for Allies and United States	$123,000,000,000
Germany	$39,000,000,000
Austria-Hungary	21,000,000,000
Turkey and Bulgaria	3,000,000,000
Total for Teutonic Allies	$63,000,000,000
Grand total	$186,000,000,000

From the above it will be seen that the total cost of the enemy nations was just one-half that of the United States and Allies.

DURATION OF THE WAR.

ALLIED AND ASSOCIATED NATIONS	WAR DECLARED BY CENTRAL POWERS	WAR DECLARED AGAINST CENTRAL POWERS	YEARS	MONTHS	DAYS
1. Serbia.........	July 28, 1914	Aug. 9, 1914	4	3	14
2. Russia*.......	Aug. 1, 1914	Nov. 3, 1914	3	7	3
3. France........	Aug. 3, 1914	Aug. 3, 1914	4	3	8
4. Belgium.......	Aug. 4, 1914	April 7, 1917	4	3	7
5. Great Britain..	Nov. 23, 1914	Aug. 4, 1914	4	3	7
6. Montenegro....	Aug. 9, 1914	Aug. 6, 1914	4	3	5
7. Japan.........	Aug. 27, 1914	Aug. 23, 1914	4	2	19
8. Portugal.......	Mar. 9, 1916	Nov. 23, 1914	3	11	19
9. Italy..........	....	May 23, 1915	3	5	19
10. San Marino....	....	June 6, 1915	3	5	4
11. Roumania†....	Aug. 20, 1916	Aug. 27, 1916	1	6	10
12. Greece........	....	Nov. 23, 1916	1	11	18
13. United States..	....	April 6, 1917	1	7	5
14. Panama.......	....	April 7, 1917	1	7	4
15. Cuba..........	....	April 7, 1917	1	7	4
16. Siam..........	....	July 22, 1917	1	3	20
17. Liberia........	....	Aug. 4, 1917	1	3	8
18. China.........	....	Aug. 14, 1917	1	2	28
19. Brazil.........	....	Oct. 26, 1917	1	..	16
20. Guatemala.....	....	April 21, 1918	..	6	21
21. Nicaragua.....	....	May 6, 1918	..	6	5
22. Haiti..........	....	July 12, 1918	..	3	30
23. Honduras......	....	July 19, 1918	..	3	23

* Peace Treaty, March 3, 1918. † Peace Treaty, March 6, 1918.

ORDNANCE PRODUCTION BY GREAT BRITAIN, FRANCE AND THE UNITED STATES—DURING THE 19 MONTHS OF AMERICAN PARTICIPATION—APRIL 6, 1917 to NOV. 11, 1918

	GREAT BRITAIN	FRANCE	UNITED STATES
Rifles....................	1,963,514	1,396,938	2,505,910
Machine Guns and Automatic Rifles..........	179,127	223,317	181,662
Rifle and Machine Gun Ammunition Rounds......	3,428,195,000	2,959,285,000	2,879,148,000
Smokeless Powder Pounds..	291,706,000	342,155,000	632,504,000
High Explosives Rounds ...	765,110,000	702,964,000	375,656,000

EXTENT OF WESTERN FRONT HELD BY ARMIES OF ALLIES AND UNITED STATES DURING 1918 EXPRESSED IN PERCENTAGES

(Italian troops are included with French, and Portuguese with British.)

1918	BELGIAN	FRENCH	BRITISH	AMERICAN
January 31	5	69	25	1
February 28	5	67	25	3
March 21	5	66	25	4
March 30	5	72	19	4
April 10	5	70	19	6
April 20	5	72	17	6
April 30	5	72	17	6
May 10	5	71	17	7
May 20	5	74	17	4
May 30	4	75	16	5
June 10	4	73	16	7
June 20	4	68	16	12
June 30	4	69	16	11
July 10	4	67	17	12
July 20	4	67	18	11
July 30	5	63	18	14
August 10	5	58	20	17
August 20	5	58	19	18
August 30	5	56	19	20
September 10	5	54	19	22
September 20	5	56	20	19
September 30	6	58	18	18
October 10	3	55	19	23
October 20	6	53	22	19
October 30	4	60	17	19
November 11	6	55	18	21

COMPARATIVE RIFLE STRENGTH OF ALLIED AND GERMAN ARMIES ON THE WESTERN FRONT, 1918

1918	GERMAN	ALLIED
April 1	1,569,000	1,245,000
May 1	1,600,000	1,343,000
June 1	1,639,000	1,496,000
July 1	1,412,000	1,556,000
August 1	1,395,000	1,672,000
September 1	1,339,000	1,682,000
October 1	1,223,000	1,594,000
November 1	866,000	1,485,000

GUNS ORGANIZED IN BATTERIES AT DATE OF THE ARMISTICE

French	11,638
Italian	7,709
British	6,993
American	3,008

BATTLE AIRPLANES IN EACH ARMY AT DATE OF THE ARMISTICE

French	3,321
German	2,730
British	1,758
Italian	812
American	740
Austrian	622
Belgian	153

BATTLE PLANES FOR EACH 100,000 MEN IN EACH ARMY AT DATE OF THE ARMISTICE

French	130
British	102
German	77
American	38

PERCENTAGES OF COMPARATIVE STRENGTH OF FRENCH BRITISH AND AMERICAN ARMIES AT THE DATE OF THE ARMISTICE

WEST FRONT, NOV. 11, 1918

	BRITISH	FRENCH	AMERICAN
Ration strength	26	41	31
Length of front held	19	59	22
Artillery in batteries	32	54	14
Airplane strength	30	57	13

PERCENTAGES OF COMPARATIVE EXPENDITURES OF AMMUNITION, DURING 1918

ALL FRONTS, 1918

	BRITISH	FRENCH	AMERICAN
Artillery Ammunition fired, including training	43	51	6
Small arms ammunition fired, including training	46	37	17

MERCHANT SHIPPING LOST THROUGH ACTS OF WAR

(In gross tons)

Great Britain		7,757,000
Norway		1,177,000
France		889,000
Italy		846,000
United States		395,000
Greece		346,000
Denmark		241,000
Holland		203,000
Sweden		201,000
Germany		187,000
Russia		183,000
Spain		168,000
Japan		120,000
Portugal		93,000
Belgium		84,000
Brazil		25,000
Austria		15,000
Other Nations		16,000
Total		12,946,000
Germany and Austria		202,000
Belligerent	10,906,000	
Neutral	1,838,000	12,744,000

SEAGOING MERCHANT SHIPPING OF THE WORLD BEFORE AND AFTER THE WAR

(In gross tons)

	July 1, 1914	Dec. 31, 1918
Great Britain	20,100,000	16,900,000
United States	1,875,000	5,719,000
Other Allies	7,675,000	6,840,000
Enemy Nations	6,325,000	4,360,000
Neutral Nations	6,640,000	5,786,000
Total	42,615,000	39,605,000
Net Decrease 3,010,000 Tons.		

THE END

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